STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

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GLACIAL GEOLOGY OF NORTHEASTERN OHIO

by

George W. White

COLUMBUS
1982

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George W. White

with a chapter on
Pleistocene beaches and strandlines bordering Lake Erie

by

Stanley M. Totten

COLUMBUS
1982

Photocopy composer: Jean M. Lesher
Cartographer: James A. Brown

PROLOGUE

The study of the glacial deposits of the Allegheny Plateau in northeastern Ohio (and elsewhere) could and will go on endlessly. This map and report are the summary of work by myself and associates over the past 50 years, and must not be delayed longer. Delay would enable the inclusion of more detail and the conclusions resulting from additional data, but something must be left for our successors! Data are continuously accumulating on chemical composition, soil properties, etc. Isotope studies give promise of information about the provenance of various deposits and may soon provide a means of extending age determinations beyond the 40,000-year limit now possible with carbon-14 dating. Geophysical methods can determine differences in certain kinds of drift layers and discontinuities. So far our knowledge has depended almost entirely on outcrops, either natural or artificial. In the future, more or less elaborate drilling programs will be routine, requiring the development of knowledge and methods of subsurface Pleistocene geology and the geologists to interpret it. Satellite imagery will be important, but because glacial geology encompasses the whole volume of material above the bedrock, a large part of the future lies in the subsurface.

The next 50 years will be as productive as the past 50 years. May our successors feel as we do, that State Geologist Newberry and his corps of assistant geologists between 1870 and 1878 and Frank Leverett in 1902 saw the "big picture," but we are glad they left parts of the canvas to be completed.

—George W. White

CONTENTS

	Page
Prologue	iii
Abstract	1
Chapter 1. Introduction	3
Purpose and scope	3
Acknowledgments	3
Previous investigations	5
Chapter 2. Description of the area	7
Bedrock geology	7
Physiography	7
Glacial lobes	10
Glacial-erosional forms	10
Chapter 3. Geomorphology of the glacial drift	12
Ground moraine or till plain	12
End moraines	12
Johnstown Moraine	13
Powell Moraine	13
Broadway Moraine	13
Mississinewa Moraine	13
St. Johns Moraine	14
Wabash Moraine	14
Fort Wayne Moraine	14
New Washington Moraine	14
Defiance Moraine	15
Spencer Moraine	15
Summit County morainic complex	15
Kent Moraine	16
Buck Hill Moraine	16
Lake Escarpment moraines	17
Euclid Moraine	17
Painesville Moraine	17
Ashtabula Moraine	18
Hummocky topography without linear trend	18
Kames and kame terraces	18
Valley trains	19
Chapter 4. Tills and related deposits	22
Classification	22
Character and composition of the till	22
Texture	22
Mineral composition	22
Color	28
Weathering character	28
Structure	29
Thickness of tills	29
Pre-Kansan? drift	29
Kansan Glacial Stage	30
Illinoian Glacial Stage	31
Pre-Mapledale and pre-Butler Illinoian tills	32
Mapledale Till	32
Location and extent	32
Composition	32
Weathering character	32
Stratigraphic position	32

	Page
Age and correlation	32
Butler Till	32
Location and extent	32
Composition	32
Stratigraphic position	34
Age and correlation	34
Distinctive Illinoian drift in Cuyahoga, Geauga, and Portage Counties	34
Sangamonian Interglacial Stage	34
Wisconsinan Glacial Stage	35
Keefus Till	35
Location and extent	35
Composition	36
Stratigraphic position	36
Age and correlation	36
Altonian Substage	36
Terminology	36
Titusville Till	37
Location and extent	37
Composition	37
Weathering character	38
Stratigraphic position	38
Age and correlation	38
Titusville outwash	39
Kames	39
Valley trains	39
Mogadore Till	39
Location and extent	39
Composition	39
Weathering character	39
Stratigraphic position	41
Age and correlation	41
Mogadore outwash	41
Kames	41
Valley trains	41
Millbrook Till	41
Location and extent	41
Composition	41
Weathering character	41
Stratigraphic position	41
Age and correlation	41
Millbrook outwash	41
Jelloway Till	41
Farmdalian Substage	42
Woodfordian Substage	43
Kent Till	43
Location and extent	43
Composition	43
Weathering character	44
Stratigraphic position	44
Age and correlation	44
Kent outwash	44
Navarre Till	44
Location and extent	44
Composition	44
Weathering character	44

CONTENTS

	Page
Stratigraphic position	44
Age and correlation	44
Knox Lake Till	44
Lavery Till	44
Location and extent	44
Composition	45
Weathering character	45
Stratigraphic position	45
Age and correlation	45
Lavery outwash	45
Hayesville Till	45
Location and extent	45
Composition	45
Weathering character	45
Stratigraphic position	46
Age and correlation	46
Mt. Liberty Till	46
Location and extent	46
Composition	46
Weathering character	46
Stratigraphic position	46
Age and correlation	46
Windham Sand	46
Hiram Till	47
Location and extent	47
Composition	47
Weathering character	47
Stratigraphic position	48
Age and correlation	48
Hiram lacustrine deposits	48
Hiram outwash	48
Centerburg Till	48
Ashtabula Till	48
Location and extent	48
Composition	49
Weathering character	49
Stratigraphic position	49
Age and correlation	49
Lakes	49
Rock Creek and Grand River Lakes	50
Lake Shelby	50
Loessial silt	51
Chapter 5. Pleistocene beaches and strandlines bordering Lake Erie, *Stanley M. Totten*	52
Introduction	52
Wave-cut cliffs and terraces	52
Upper (Maumee) Cliffs and Terraces	52
Middle (Whittlesey) Cliff and Terrace	54
Lower (Warren) Cliffs and Terraces	55
Cliffs and terraces below the Lower (Warren) Terrace	55
Dating of cliffs and terraces	56
Strandlines cut into bedrock	56
Beach ridges	56
Maumee beach ridges	57
Whittlesey beach ridges	58
Arkona beach ridges	58
Warren beach ridges	58
Other beach ridges	59
Chronology of beach ridges	60
Chapter 6. Pleistocene history	61
Introduction	61
Nebraskan Stage	61
Aftonian Stage	61
Kansan Stage	61
Yarmouthian Stage	61
Illinoian Stage	62
Sangamonian Stage	62
Wisconsinan Stage	62
Altonian Substage	62
Farmdalian Substage	64
Woodfordian Substage	64
Kent-Navarre advance	64
Lavery-Hayesville advance	66
Hiram advance	67
Ashtabula advance	68
Chapter 7. Mineral resources	69
Introduction	69
Sand and gravel	69
Ceramic products	70
Water supply	70
Chapter 8. Environmental and engineering geology	71
Introduction	71
Vertical variation in drift materials	71
Landslides	71
Boulder pavements	71
Environmental aspects of geomorphic areas	71
Ground moraine	71
End moraines and other hummocky topography	72
Kames and kame terraces	72
Valley trains	72
Outwash plains and lake plains	72
Swamps and kettle holes	72
Chapter 9. Summary	73
References cited	73

FIGURES

1. Location of study area and glacial boundary in Ohio	4
2. Woodcut of kames in Portage County	5
3. Bedrock geology of northeastern Ohio	8
4. Physiographic divisions in northeastern Ohio	8
5. Ice-sheet margins in northeastern Ohio	9
6. End moraines in northeastern Ohio	in pocket
7. Sketch of a section of Buck Hill, a kame in western Canton, Stark County	19
8. Profile of terraces on the north side of the Ohio River valley at East Liverpool, Columbiana County	21
9. Generalized cross sections across Summit County	23
10. Sketch of tills in cut for I-80, 1½ miles southwest of the center of Girard, Trumbull County	24
11. Percentage of feldspar in Kent Till of Grand River lobe in Ohio and Pennsylvania	26

CONTENTS

	Page
12. Average weathering horizons of tills in northeastern Ohio	27
13. "Succession of material" in "clay-drift" in northern Summit County	28
14. Histograms of thicknesses of Woodfordian (late Wisconsinan) tills	30
15. Sketch of glacial deposits exposed in deep pit of Derwacter Sand and Gravel Co., Jefferson Township, Richland County	31
16. Sketch of tills in strip mine, Center Township, Columbiana County	33
17. Sketch of section exposed in excavation for parking lot on the north side of Gilchrist Road just west of the I-76 underpass, East Akron, Summit County	33
18. Sections of tills in Ashland County showing Illinoian and Wisconsinan drifts	34
19. Sketch of Farmdalian loesses and Sangmonian paleosol overlying Illinoian gravel exposed in pit of Cleveland Sand and Gravel Co., 1 mile southeast of Garfield Park, Cleveland	35
20. Sketch of the type section of the Keefus Till exposed in the north bank of Conneaut Creek 50 yards east of the Keefus Road bridge, Conneaut Township, Ashtabula County	36
21. Sketch of multiple Titusville tills forming the bulk of the Kent Moraine in an exposure in clay pit of Whitacre-Greer Co., Knox Township, Columbiana County	38
22. Weathering horizons of Mogadore Till	40
23. Sketch of glacial deposits exposed along the wall of an inactive gravel pit, Cass Township, Richland County	42
24. Sketch of small buried interglacial valley exposed on northwest side of excavation for I-71, Perry Township, Morrow County	43
25. Stratigraphic relation of Windham Sand as shown in excavations for Ohio Turnpike bridge over B & O Railroad, 2 miles east of Newton Falls, Trumbull County	47
26. Sketches of lake bluff at Camp Luther, 1 mile west of east line of Kingsville Township, Ashtabula County	49
27. Map of Rock Creek and Grand River Lakes in Ashtabula and Trumbull Counties	50
28. Composite cross section of strandlines south of Lake Erie in Lorain and western Cuyahoga Counties	53
29. Composite profile of strandlines south of Lake Erie in eastern Cuyahoga County	53
30. Composite cross section of strandlines south of Lake Erie in Lake and Ashtabula Counties	54
31. Elevations of intersections of cliffs and terraces in northeastern Ohio	55
32. Elevations of beach-ridge crests in northeastern Ohio	56
33. Comparison of elevations of beach-ridge crests and cliff-terrace intersections	57
34. Relationship between the elevations of beach ridges and their ages	59
35. Time-space diagram showing stratigraphic classification of tills in Grand River and Killbuck lobes	62
36. Altonian (Titusville-Mogadore-Millbrook-Jelloway) ice margins in northeastern Ohio	63
37. Early Woodfordian (Kent-Navarre) ice margins in northeastern Ohio	64
38. Middle Woodfordian (Lavery-Hayesville) ice margins in northeastern Ohio	65
39. Late Woodfordian (Hiram) ice margin in northeastern Ohio	66
40. Latest Woodfordian (Ashtabula) ice margin in northeastern Ohio	67

TABLES

1. Glacial stages of the Pleistocene Epoch	24
2. Correlation of tills in northeastern Ohio	25
3. Mean grain size and feldspar content of the tills	25
4. Average composition of tills of the Grand River lobe	25
5. Average composition of tills of the Killbuck lobe	26
6. Thickness of Wisconsinan tills	29
7. Beach ridges of northeastern Ohio	60

PLATE

1. Glacial geology of northeastern Ohio .... accompanying report

GLACIAL GEOLOGY OF NORTHEASTERN OHIO

by

George W. White

ABSTRACT

The Allegheny Plateau, the westernmost part of the Appalachian Plateaus, extends into eastern Ohio and makes up almost half of the state. That part of the Plateau in northeastern Ohio was glaciated by several ice sheets which extended varying distances south of Lake Erie. The maximum advance of the glaciers was to a line 60 to 80 miles south of Lake Erie. The glacial boundary extends from Pennsylvania into northeastern Ohio across Columbiana, Stark, Holmes, and Ashland Counties to the extreme southeastern corner of Richland County, whence it turns abruptly south and continues to the Cincinnati region. The counties in northeastern Ohio that have been glaciated are Ashland, Ashtabula, Columbiana, Cuyahoga, Geauga, Holmes, Lake, Lorain, Mahoning, Medina, Portage, Richland, Stark, Summit, Trumbull, and Wayne Counties.

The bedrock consists mainly of sandstone, shale, limestone, and coal of Pennsylvanian age and sandstone, siltstone, and shale of Mississippian age. Shale of Devonian age underlies the Lake Plain and small areas south of it.

The area is mainly a dissected plateau in very early maturity to middle maturity at elevations from 900 to 1,500 feet, but generally from 1,050 to 1,200 feet. In Cuyahoga, Medina, Ashland, and Richland Counties a lower part called the Low Plateau extends along the margin of the higher Plateau at elevations of 900 to 1,000 feet. A narrow Lake Plain borders Lake Erie and is separated from the Plateau by the Escarpment, which is the northern margin of the Allegheny Plateau.

The ice of the Pleistocene advanced in a series of lobes. In northeastern Ohio and adjacent areas the Erie lobe advanced into the Erie basin. Smaller lobes controlled by topography formed in the southern part of the Erie lobe in the later part of the Pleistocene Epoch. The Grand River lobe extended southward in the lower land between the highland of northwestern Pennsylvania and that of Geauga County, Ohio. The Killbuck lobe extended southward in the lower land between the highland in Medina and Summit Counties and the highland in western Richland County. At times the small Cuyahoga lobe extended southward in Cuyahoga and northern Summit Counties between the Grand River and Killbuck lobes. The Scioto lobe extended far to the south in the Central Lowland between the Richland County highland and the highland of the Bellefontaine outlier in Logan County. Only the eastern margin of the Scioto lobe advanced easterly onto the Plateau in Richland County and south of the study area in Knox and Licking Counties and counties farther south.

Some valleys were deepened as much as 300 feet or more by erosion as the ice advanced over the Plateau, but uplands were reduced only a few feet or tens of feet and some bedrock hills were smoothed into streamlined forms.

The geomorphic forms of the drift deposits are controlled in large part by the composition of the drift. Some deposits are composed of till, ice-laid material which is an unsorted mixture of clay, silt, sand, pebbles, cobbles, and boulders; other deposits are composed of outwash, stratified sand and gravel. The till may form a more or less smooth sheet—ground moraine—or be aggregated in irregular hummocks arranged in lines or belts to form end moraines. End moraines are most clearly displayed in the western part of the Killbuck lobe where there are areas of ground moraine between the end moraines. The ridgelike end moraines of the Killbuck lobe are, from south to north, the Johnstown, Powell, Broadway, Mississinewa, St. Johns, Wabash, Fort Wayne, Defiance, and Spencer Moraines. The Buck Hill Moraine lies along the east side of the Killbuck lobe in Stark and Summit Counties and is in juxtaposition with the Kent Moraine on the west side of the Grand River lobe in southern Summit and northern Stark Counties. The Defiance Moraine extends across the Killbuck, Cuyahoga, and Grand River lobes north of the other moraines (except the Spencer). The Kent Moraine is a 3- to 8-mile belt of more or less pronounced hummocks along the margin of the Grand River lobe. The Lake Escarpment moraines are prominent features upon the Escarpment and on the margin of the Plateau in Cuyahoga, Lake, and Ashtabula Counties. From south to north, they are the Euclid, Painesville, and Ashtabula Moraines.

Outwash deposits of sand and gravel are in the form of kames, kame terraces, valley trains, and outwash plains. Kames are irregular sharp knolls; kame terraces are aggregations of kames along valley sides. Kames and kame terraces are particularly prominent in Geauga, western Portage, much of Summit, and northern Stark Counties. Valley trains are smooth outwash deposits in valleys; they may now remain only as terraces below kame terraces along valley sides because of later stream erosion. Kettle holes are depressions left when remnant ice masses melted in kames, kame terraces, or outwash plains. The kettle holes range in size from an acre to many square miles. They are the sites of swamps and lakes, such as the Portage Lakes of Summit County.

The drift of northeastern Ohio was deposited by glaciers from very early Pleistocene to late Pleistocene age. The earliest deposits, of Nebraskan or even earlier age, are represented by exceedingly rare erratic boulders a few miles south of the glacial boundary as mapped; by silts on uplands many tens of miles beyond the glacial boundary; by deposits of lakes formed by early Pleistocene damming of northward-flowing streams; and by a few deeply weathered terrace remnants of a very early valley train at an elevation of 980-1,020 feet in the Ohio River valley.

Kansan-age deposits are represented by the much-weathered Slippery Rock Till found below later deposits in a few places.

The Mapledale Till of Illinoian age is discontinuously present in the subsurface in the Grand River lobe. The correlative Butler Till of the Killbuck lobe crops out in southern Richland County and is present in the subsurface in the remainder of the Killbuck lobe. These Illinoian tills are coarse, sandy, and very low in carbonates. Unnamed Illinoian tills are present at a few places below the Mapledale and Butler Tills. Partly preserved Sangamonian paleosol is present upon the Mapledale and Butler Tills. Outwash of Illinoian age is present in the Ohio River valley as remnants of valley trains at an elevation of about 790-810 feet.

The Wisconsinan deposits are of Altonian, early Wisconsinan, and Woodfordian, late Wisconsinan, age. However, in northern Ashtabula and Lake Counties, a pre-Altonian reddish Keefus Till occurs. Its age is uncertain, as no weathered material has been seen upon it; it is tentatively regarded as very early Wisconsinan.

The Altonian tills—Titusville Till of the Grand River lobe, Mogadore Till of the Cuyahoga lobe, Millbrook Till of the Killbuck lobe, and Jelloway Till of the Scioto lobe—are the thickest tills of northeastern Ohio and in most places make up the bulk of the drift. Altonian tills are sandy, coarse, compact, and have prominent joints that are stained. Prominent kame and valley-train deposits of Altonian age are economically important.

Farmdalian paleosol occurs at many places upon the Altonian tills below overlying Woodfordian tills.

The early Woodfordian tills—Kent Till of the Grand River and Cuyahoga lobes, Navarre Till of the Killbuck lobe, and Knox Lake Till of the Scioto lobe—are coarse and sandy, but not as compact as the underlying Titusville Till and equivalents. The oxidized early Woodfordian tills are yellow brown in contrast to the olive brown of the Altonian tills. The early Woodfordian tills are much thinner than the Altonian tills and may be absent in some areas, so that Altonian till is at the surface.

Tills of late Woodfordian age are very different in character from earlier tills. The Lavery Till of the Grand River and Cuyahoga lobes, the Hayesville Till of the Killbuck lobe, and the Mt. Liberty Till of the Scioto lobe are silty tills with fewer pebbles and cobbles than the earlier tills. They are generally only 2 to 6 feet thick and weather to a dark-brown color. The Lavery Till and equivalents are unique in that in the outer 3-10 miles they are so very discontinuous, thin, and rarely evident.

The Windham Sand is present between the Lavery Till and the younger Hiram Till in eastern Portage and southwestern Trumbull Counties. It is fine sand ranging from a foot or less to 20 feet in thickness.

The late Woodfordian Hiram Till can be traced continuously on the surface across all the lobes and into the Centerburg Till of the Scioto lobe. The Hiram Till is clayey, silty, and calcareous with very few cobbles. It is generally thin and is missing at many places, so that the Lavery Till or its correlatives are at the surface.

The Ashtabula Till, the youngest till in Ohio, occurs only in a belt 3 to 6 miles wide parallel to the Lake Erie shore in eastern Cuyahoga, Lake, and Ashtabula Counties. It is partly removed by erosion on the Lake Plain but is well exhibited as the uppermost till of the Lake Escarpment moraines. The Ashtabula Till is a silty till containing abundant shale particles.

Silt of windblown origin (loess) occurs at many places as a cap as much as 2 feet thick, but generally less than that, upon the underlying material.

Two prominent sets of Wisconsinan strandlines occur in more or less parallel bands on the Lake Plain. The older set dates from the Farmdalian Stage when lake levels were mostly higher than present and consists of wave-cut cliffs and terraces. The younger set of strandlines consists of approximately 20 beach ridges, which formed on the Farmdalian-age terraces during final Woodfordian ice retreat from the Erie basin. These sand and gravel ridges, which represent stages of Lakes Maumee, Whittlesey, and others, occur between the elevations of 780 and 612 feet and formed over a period of about 1,800 years during a gradual lowering of lake level.

Pleistocene history is recorded in the deposits, in the erosional forms, and in the ancient soils. The Nebraskan (or even earlier?) Stage ice advanced to approximately the glacial boundary as mapped or a little farther at some places. The evidence is so meager that little can be said about the number and ages of the earliest advances, but the onset of the earliest ice of the Pleistocene Epoch is now believed to have been about 2 million years before present.

The Kansan Stage, which may have begun 500,000 years before present, is recognized by very widely scattered much-weathered till, and by deeply weathered outwash terraces in the Ohio River valley near East Liverpool at elevations of 980 to 1,020 feet.

The Yarmouthian Stage, a long period of erosion and weathering, lasted perhaps 200,000 years. During the Illinoian Stage ice advanced more than once to the limit of advance of later Wisconsinan ice, but a very late Illinoian advance took place only in Cuyahoga, Geauga, and Portage Counties, and by implication in Lake, Ashtabula, and part of Trumbull Counties.

The Sangamonian Stage of weathering and erosion followed the retreat of the Illinoian ice about 125,000 years before present and lasted perhaps 50,000 years.

In the Wisconsinan Stage several ice advances took place. The earliest advance reached only Lake and Ashtabula Counties and deposited the distinctive reddish Keefus Till. The Altonian Substage ice advanced about 40,000 years before present as one or more ice sheets and deposited the distinctive coarse Titusville-Mogadore-Millbrook-Jelloway Tills, which are the thickest of any of the Pleistocene deposits. The Altonian ice withdrew an unknown distance north of Lake Erie about 28,000 years before present. This ice sheet released abundant meltwater, which deposited tremendous amounts of gravel and sand in kames, kame terraces, and valley trains, which extended down all the southward-flowing streams to the Ohio River and thence down the Ohio River. Almost all the gravel of northeastern Ohio was deposited during the Altonian Substage.

The Farmdalian Substage was a time of erosion and some loess deposition and extended from about 28,000 to 23,000 years before present.

The Woodfordian Substage began about 23,000 years before present. The first advance was that which deposited the moderately coarse Kent-Navarre-Knox Lake Tills and was the earliest advance in which the ice was divided into the Grand River, Cuyahoga, Killbuck, and Scioto lobes. This advance reached 1 to 3 miles within the limit of the Altonian ice advance. The Kent ice then retreated at least as far as the Erie basin.

About 19,000 years before present the Lavery-Hayesville-Mt. Liberty ice advanced from the Erie basin to within 2 to 5 miles of the limit of the preceding advance. The dynamics of the outer 3 to 10 miles of this ice sheet were such that the ice deposited only very thin and very discontinuous patches of till.

The Lavery-Hayesville-Mt. Liberty ice retreated into the Erie basin and the Hiram ice sheet quickly advanced about 17,000 years before present. The Hiram ice extended across all of northeastern Ohio but did not reach as far south as earlier Woodfordian ice. The Hiram ice deposited a clayey silty till with few pebbles. Upon retreat of the Hiram ice into the Erie basin about 15,000 years before present, Ashtabula ice advanced from the basin to only about 6 miles south of the present Lake Erie shore. The Ashtabula ice picked up not only much silt and clay from the lake bed but also much shale and siltstone from the basin of Lake Erie and incorporated them into the till it deposited. The Erie lobe in Ashtabula time extended only as far as Cleveland, where its margin turned north across glacial Lake Erie.

Upon retreat of the Ashtabula ice about 14,500 years before present, ancient Lake Erie existed at a level of about 780 feet as glacial Lake Maumee. Continued retreat of Woodfordian ice uncovered lower outlets across Michigan and New York State, dropping the lake level lower and lower until the lake was nearly drained. Isostatic uplift of the Niagara outlet during the Holocene has resulted in raising the water level to the present 571 feet.

The mineral resources of glacial origin are important. Gravel and sand occur in every county, but the deposits in Geauga, Summit, Portage, Stark, Wayne, and Columbiana Counties are the most abundant. Gravel and sand now covered by till of differing thickness will be important resources in the future. The gravel and sand at depth provide abundant water supplies, but these are not everywhere present.

The glacial deposits possess different engineering characteristics at different depths because the deposits differ both horizontally and vertically, so that excavations and construction must take the stratigraphy and the composition of the strata into account. The interfaces between the deposits are important, as they may be paths for fluid travel. Landslides are likely to occur on steeper slopes, especially in areas of silty and clayey tills of late Woodfordian age. Solid- and liquid-waste disposal must take into account not only the various stratigraphic units but also the interfaces between them.

The environments of the glaciated region of northeastern Ohio range from flat poorly drained ground moraine, to irregular surfaces of the end moraines and kames, to the swamps and lakes in kettle holes. By taking into account the various glacial forms, deposits, and properties, the best use can be determined for the glaciated Plateau in northeastern Ohio.

Chapter 1

INTRODUCTION

PURPOSE AND SCOPE

This map and report on the glacial geology of the Allegheny Plateau of northeastern Ohio have been prepared to show (1) the extent of the glaciated region; (2) the different topographic forms of the till deposits–end moraine, hummocky topography, and ground moraine; (3) the extent of outwash deposits–outwash plains, valley trains, kames, and kame terraces; (4) the extent of the various till sheets; and (5) the extent of lake deposits, with associated raised beaches of ancient Lake Erie. Sixteen counties in northeastern Ohio are included in this report: Ashland, Ashtabula, Columbiana, Cuyahoga, Geauga, Holmes, Lake, Lorain, Mahoning, Medina, Portage, Richland, Stark, Summit, Trumbull, and Wayne (fig. 1).

Ice advanced into northeastern Ohio from the Erie basin and spread generally southward. The earliest ice sheet advanced to a line through Columbiana, Stark, Holmes, Ashland, and Richland Counties. Later ice sheets did not advance nearly as far. Each advance deposited drift–unsorted till and sorted sand and gravel. The till of each advance has distinctive characteristics which enable differentiation among the various till sheets.

The text of this report discusses the general setting, form, composition, and character of the various deposits and the Pleistocene history that these deposits reveal. An important purpose is to discuss the relationship of the glacial forms and material to engineering projects, waste disposal–both solid and liquid–and water supply. The mineral resources of the glacial material also are discussed.

This report and map are a compilation from individual county reports and maps (see p. 5). Some generalization has been necessary in reducing county maps at a scale of 1 inch to 1 mile (1:62,500) to this regional map at a scale of 1 inch to 4 miles (1:250,000).

The scope of this report is limited to discussions of the glacial deposits. Only enough of the general physiography of the region is included to provide a setting for the glacial deposits and their history. The fascinating and complicated history of drainage changes caused by the advance of the various ice sheets is not included in this report. Inasmuch as the report and map are based on detailed reports of each county and on a number of other papers, it will not repeat all the details of analyses of material and detailed descriptions of glacial forms, but will make reference to the many extensive publications for the use of those concerned with the details of a specific area or specific topic.

ACKNOWLEDGMENTS

Many men and organizations have contributed to this study, which has extended over a large area and lasted for almost 50 years. A University Fellowship at the Ohio State University in 1932-1933 provided in part for field work in the area of the western part of the Killbuck lobe and the northeastern part of the Scioto lobe. A research grant from the Geological Society of America in 1941 enabled field work in the region of the fringe drift in the Grand River lobe.

A large part of the investigation was made between 1949 and 1964 during a part-time U.S. Geological Survey appointment in a cooperative program with the Ohio Department of Natural Resources, Division of Water. This work was under the direction of E. J. Schaefer, District Engineer, from 1949 to 1952, and S. E. Norris, District Geologist, from 1952 to 1964. The support and encouragement of each of these men were essential to the investigation.

In the early years of the cooperative investigations, R. C. Smith and I worked together in Summit County, and then J. D. Winslow and I worked together in Cuyahoga and Portage Counties. Smith and Winslow were studying the bedrock and hydrogeology, but provided much assistance on the glacial investigations.

The work of J. B. Droste on clay minerals and of V. C. Shepps, D. L. Gross, and S. R. Moran on textural and statistical analyses added greatly to our knowledge. Their effective aid in the field from time to time is a pleasure to record. R. F. Sitler, who worked chiefly in Pennsylvania, provided information from his thin-section studies. Jack Baker provided detailed work on Geauga County. The comments and advice of H. D. Lessig on soils as related to geology in Columbiana, Mahoning, Portage, and Stark Counties has been most helpful. Although the part of this report dealing with Cuyahoga County is based on the report by Winslow, White, and Webber (1953), comments by J. P. Ford, based on his study of Cuyahoga County (manuscript with the Division of Geological Survey), have been helpful.

Since 1947 the University of Illinois has provided office facilities and support for manuscript preparation through provision of a series of expert student secretaries, who not only typed repeated drafts of analyses and reports, but assisted with bibliographies and similar compilations. The National Science Foundation, in a series of grants through the University of Illinois, has provided support for research assistants in the field in Pennsylvania and Ohio and for laboratory work on Pennsylvania and Ohio drift material.

I am particularly indebted to S. M. Totten, once my student and since 1963 my associate in the field and coauthor of many reports. He has contributed to sharpening the field observations and shaping ideas of history and genesis of the deposits. Totten's work in rapid identification of quartz and feldspar to confirm identifications of separate tills was demonstrated by a succession of assistants. His

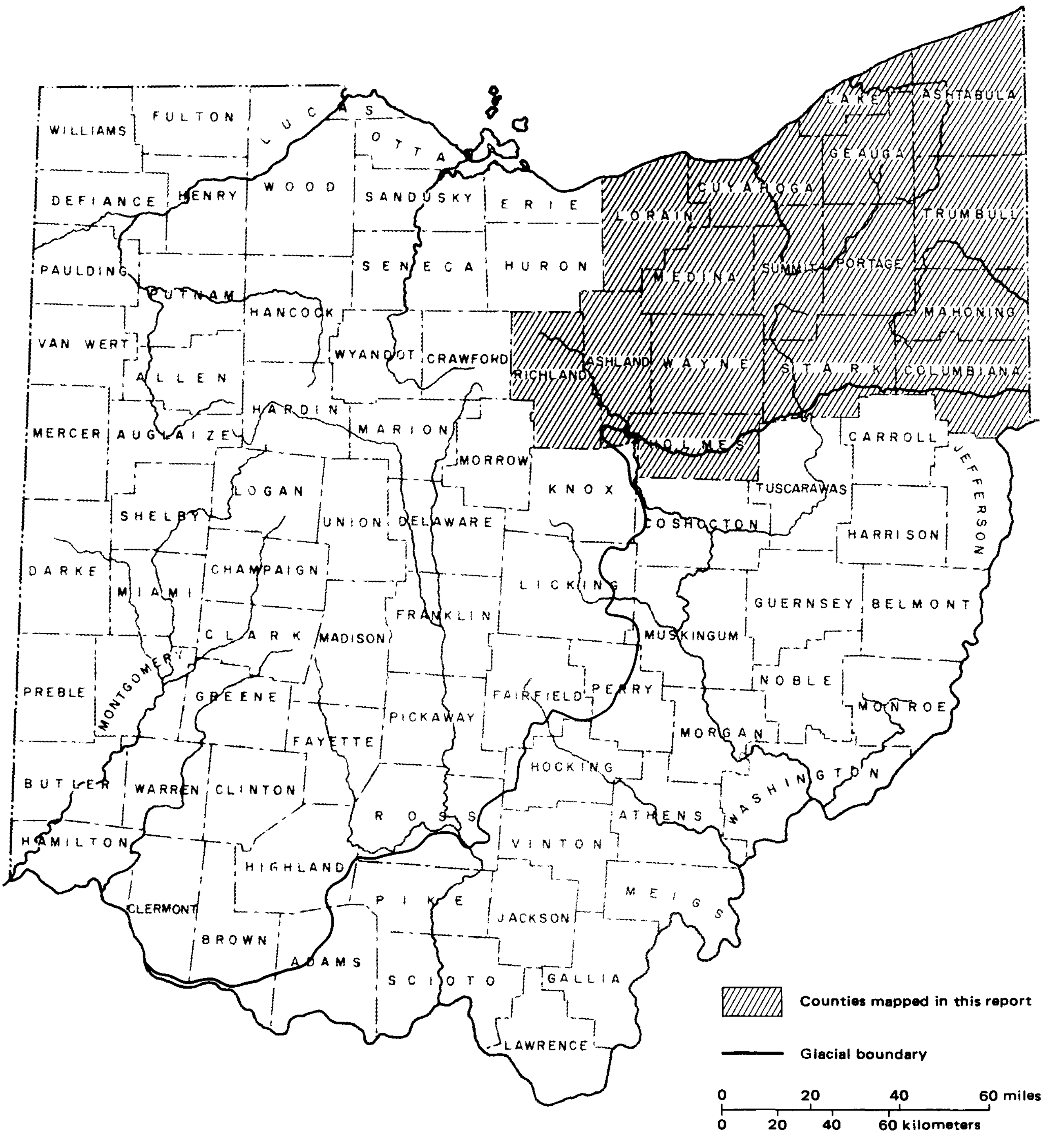


FIGURE 1.–Location of study area and glacial boundary in Ohio.

analytical approach in the field has tempered my impulsive enthusiasm; Totten has convinced me, sometimes reluctantly, of important principles—thin tills and buried moraines, to name only a few. His maps and reports on Richland, Medina, and Lorain Counties have been used in this report. Our joint authorship of the reports on Ashtabula, Columbiana, and Mahoning Counties are as much his as mine; the Mahoning County report is essentially Totten's work. His penetrating surface and subsurface study has revised our concept of the formation of beach ridges and cliffs.

Since 1970 H. R. Collins, State Geologist, has been a consultant and valuable advisor in the field and office work. Merrianne Hackathorn and S. E. Shear provided editorial assistance in the presentation of text, diagrams, and maps of this report. The maps and diagrams have been expertly constructed by J. A. Brown.

Since 1928 my best friend and severest critic, my wife, Mildred K. White, has cheerfully moved to field headquarters at various places in northeastern Ohio for more than 10 summers, has helped with the office work from time to time, has pointed out correct syntax and expression, and has insisted on clarity and elimination of unnecessary technical expressions. She has shared the pleasure of seeing each county report and map finally appear after long work.

PREVIOUS INVESTIGATIONS

Although observations on glacial deposits in Ohio were made as early as 1803 and other observations were made at various times since then (see White, 1973, 1976; White and Legget, 1981), the first organized report on glacial geology in Ohio, including northeastern Ohio, was that of J. S. Newberry in 1874. In this report he summarized the glacial geology from the county reports of the Second Geological Survey of Ohio that were already published or in press. He recognized in a general way the glacial boundary in northeastern Ohio and described at more or less length the materials of the drift. His diagrams and maps are valuable and the woodcuts are charmingly clear and useful (fig. 2). The county reports on which Newberry based his synthesis are referenced in the recent county reports (see below) on which this report is based.

The reports of G. F. Wright (1884a, 1884b, 1890) described the marginal drift and for the first time accurately showed the glacial boundary. An especially noteworthy contribution was the recognition of the narrow fringe of discontinuous drift and the mapping of its extent. The age of this fringe was puzzling and continued to be controversial for more than 80 years.

F. R. Leverett's (1902) monumental monograph on the Erie and Ohio basins described in detail the glacial deposits of Ohio and adjacent states. He named the glacial lobes in northeastern Ohio the Grand River lobe, the "shoulder of the Scioto Lobe" (now called the Killbuck lobe), and the Scioto lobe. He mapped in detail the glacial boundary and showed the fringe of earlier drift, about whose age he was not certain. He introduced the classification of Wisconsin (now Wisconsinan), Illinoian, and Kansan drift in Ohio and stated that the surface drift of northeastern Ohio was Wisconsin[an], but that some subsurface material might be Illinoian. He considered drainage changes in detail.

G. W. White's (1933) report on the geology of the Knox-Richland-Ashland County area dealt largely with surface features. The term Killbuck lobe was proposed for Leverett's "shoulder of the Scioto lobe."

The glacial map of Ohio by Goldthwait, White, and Forsyth (1961) shows end moraines, ground moraine, lake deposits, and outwash deposits—valley trains and kames. The fringe drift of Columbiana and Stark Counties which is shown as Illinoian is now known to be early Wisconsinan (Altonian). Almost all the "Illinoian drift" of the Scioto lobe in Knox and Licking Counties also now is regarded as Altonian. Some substage boundaries are shown on the glacial map of Goldthwait, White, and Forsyth; the Hiram Till (not named) boundary is reasonably accurate.

Work in northwestern Pennsylvania (Shepps and others, 1959), where the older drift occupies a wider area than in Ohio, enabled the tracing of the older drift into Ohio. Carbon-14 analyses from Pennsylvania showed that the fringe drift in Ohio was Titusville Till of early Wisconsinan (Altonian) age (White, Totten, and Gross, 1969).

A summary of the drift sheets in northeastern Ohio and northwestern Pennsylvania was presented by White in 1969. The current stratigraphic classification was first published for the Grand River lobe in 1960 (White, 1960) and for the Killbuck lobe in 1961 (White, 1961).

The county reports and maps (scale 1:62,500) on which this summary report and map are based are listed below. The following county reports have been published: Ashland County (White, 1977), Ashtabula County (White and Totten, 1979), Cuyahoga County (Winslow, White, and Webber, 1953), Holmes County (White, 1973a), Lake County (White, 1980), Portage County (Winslow and White, 1966), Richland County (Totten, 1973), Stark County (DeLong and White, 1963), Trumbull County (White, 1971b), and Wayne County (White, 1967). See References cited for complete citations. The glacial geology of the counties for which reports were published early in the term of this study has been refined or revised on the basis of later work.

Manuscripts are completed for the following counties and the reports will be published by the Division of Geological Survey: Columbiana County (White and Totten), Lorain County (Totten), Mahoning County (Totten and White), Medina County (Totten), and Summit County (White). Mapping for Geauga County was based on an unpublished dissertation (Baker, 1957) and additional unpublished information from Jack Baker. A manuscript on the glacial geology of Geauga County is being prepared by S. M. Totten and will be published by the Division of Geological Survey.

GRAVEL HILLS, RANDOLPH, PORTAGE COUNTY.

From 50 to 100 feet high; 500 feet above Lake Erie.

FIGURE 2.—Woodcut of kames in Portage County (from Newberry, 1878, p. 42).

The many papers reporting on clay mineral and other mineral composition of the tills, on statistical analyses, and on other details are mentioned later and in the various county reports. Recent very detailed maps and reports on the soils of some of the counties also are mentioned later.

This report does not deal with the fascinating history of drainage changes caused by repeated advances of Pleistocene ice sheets. The early reports on drainage changes assumed that all abandoned valleys were preglacial, but later reports recognized that the diversions had occurred at various times and that many abandoned valleys are interglacial and not preglacial. The complexity of the sequence of drainage diversions is now recognized and maps of diversions at different times are now regarded only as very tentative. The bibliography of Ohio geology (Smyth, 1979) lists the many publications on this subject. An excellent general view of the deep, wholly or partially buried bedrock valleys in northeastern Ohio is the map of Cummins (1959). The very extensive report by Stout, Ver Steeg, and Lamb (1943, p. 51-106) deserves special mention.

Chapter 2

DESCRIPTION OF THE AREA

BEDROCK GEOLOGY

The bedrock of the Allegheny Plateau in northeastern Ohio is Mississippian and Pennsylvanian in age (fig. 3). The Mississippian rocks are siltstones and sandstones, generally fine grained. The Pennsylvanian rocks are conglomerates, sandstones, shales, and thin limestones and coals. In a belt along Lake Erie the bedrock is Devonian shale of the thick Chagrin Shale Member of the Ohio Shale.

The strata dip gently to the south and south-southeast at about 30 feet per mile. Important coal beds of the Allegheny Group (Pennsylvanian) are preserved in the southern part of the glaciated area, chiefly in Mahoning, Columbiana, Stark, southeastern Wayne, and northeastern Holmes Counties. Considerable areas in these counties have been surface mined for coal, and thus the whole section of glacial drift has been exposed. It is from these outcrops that much of the information about lower glacial units is derived.

PHYSIOGRAPHY

The detailed discussion of the major physiographic features of northeastern Ohio is not part of this report, but a general summary is presented here as a basis for the geomorphology of the glacial drift and of the glacial-erosional forms which are discussed in the following section.

Two very contrasting physiographic divisions are present in northeastern Ohio (fig. 4). Almost all of the area is in the Allegheny Plateau except a small section of much lower Lake Plain adjacent to Lake Erie. The Allegheny Plateau, also referred to here as "the Plateau," is the northwestern part of the larger Appalachian Plateaus Province. The glaciated plateau differs markedly from the unglaciated plateau to the south in that it has suffered more or less glacial erosion, tending to smooth the uplands, excavate deep valleys now partly filled by glacial drift, and more or less smooth the bedrock topography by covering it with drift deposits.

The northern and northwestern boundary of the Allegheny Plateau is also the southern boundary of the Lake Plain and is a prominent escarpment, here referred to as "the Escarpment," extending from the Ohio-Pennsylvania state line across Ashtabula and Lake Counties to western Cuyahoga County. The Escarpment is not a single line or steep cliff but a composite feature forming a belt as much as 3 miles wide against which is deposited a series of prominent end moraines. The Escarpment is described in some detail in the report on Ashtabula County (White and Totten, 1979).

The Allegheny Plateau ranges from an elevation of 950 feet or a little less on the north to between 1,500 and 1,520 feet southwest of Mansfield, Richland County. Most of the Plateau ranges from 1,050 to 1,200 feet in elevation. It is generally maturely dissected by valleys as much as 500 feet deep. These bedrock valleys are filled with as much as 200 feet of glacial deposits, so their present bottoms are 300 feet or so below the present surface. The dissection reached the stage of early maturity before glacial time in much of the area so that a great part of the upland surface is reasonably level. Present dissection in northeastern Ohio has reached only late youth, and wide areas of level land exist in Ashtabula, Trumbull, northern Mahoning, eastern Portage, northern Ashland, and northern Richland Counties.

Erosion levels are not discussed in this report, but two major levels at about 1,200 to 1,100 feet are evident. For details see the articles listed by Smyth (1979) under "Geomorphology, Erosion surfaces," and an excellent discussion by Stout and Lamborn (1924, p. 36-45).

The term "Low Plateau" (White, 1933) is a name applied to a belt from 5 to 15 miles wide along the northwestern margin of the Plateau extending across parts of Cuyahoga, Lorain, Medina, Ashland, and Richland Counties. Berea Sandstone of Mississippian age is the bedrock. The eastern boundary is marked by the generally abrupt rise to the higher main Allegheny Plateau. Its western boundary is along a scarp that follows the outcrop of the resistant Berea Sandstone, which rises 50 to 100 feet above the till plain. The relief of the Low Plateau ranges from only a few feet to as much as 100 feet, but averages less than 50 feet. It is covered by a thick blanket of drift so that its topography is glacially controlled.

Bordering Lake Erie from the Ohio-Pennsylvania state line to Cleveland, Cuyahoga County, is a narrow plain, here referred to as "the Lake Plain," up to 7 miles wide, but averaging 4 miles. The margin at Lake Erie (average level 571 feet) is generally a cliff ranging from 20 feet at places in Cuyahoga and western Lake Counties to almost 80 feet in northeastern Ashtabula County. The cliff is breached by streams which enter Lake Erie. The south margin of the Lake Plain is the Escarpment of the Allegheny Plateau.

The elevation of the Lake Plain is about 620 feet at the top of the lake cliff, rising southward to about 660 feet in approximately 3 miles and thence to 750 to 780 feet in the remaining mile to the base of the Escarpment. The surface, except for the beaches of ancient lakes and for the southernmost mile or so, is so level that drainage is poor. The bedrock of the Lake Plain, the Chagrin Shale Member of Devonian age, is close to the surface in part of the area and is exposed in almost all the stream valleys.

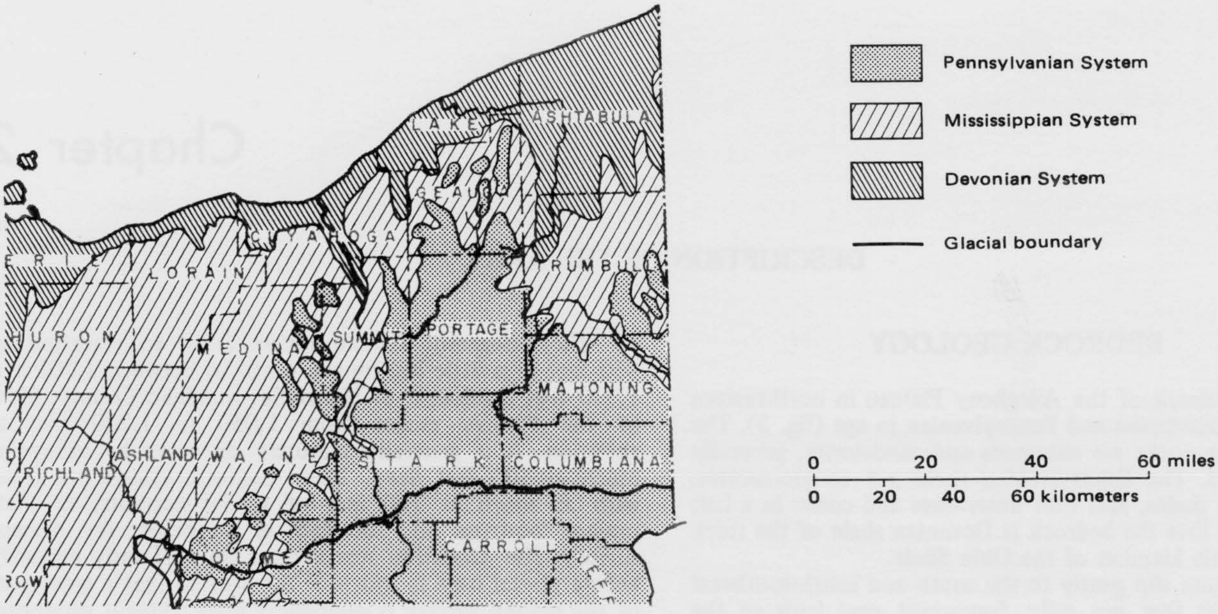


FIGURE 3.–Bedrock geology of northeastern Ohio.

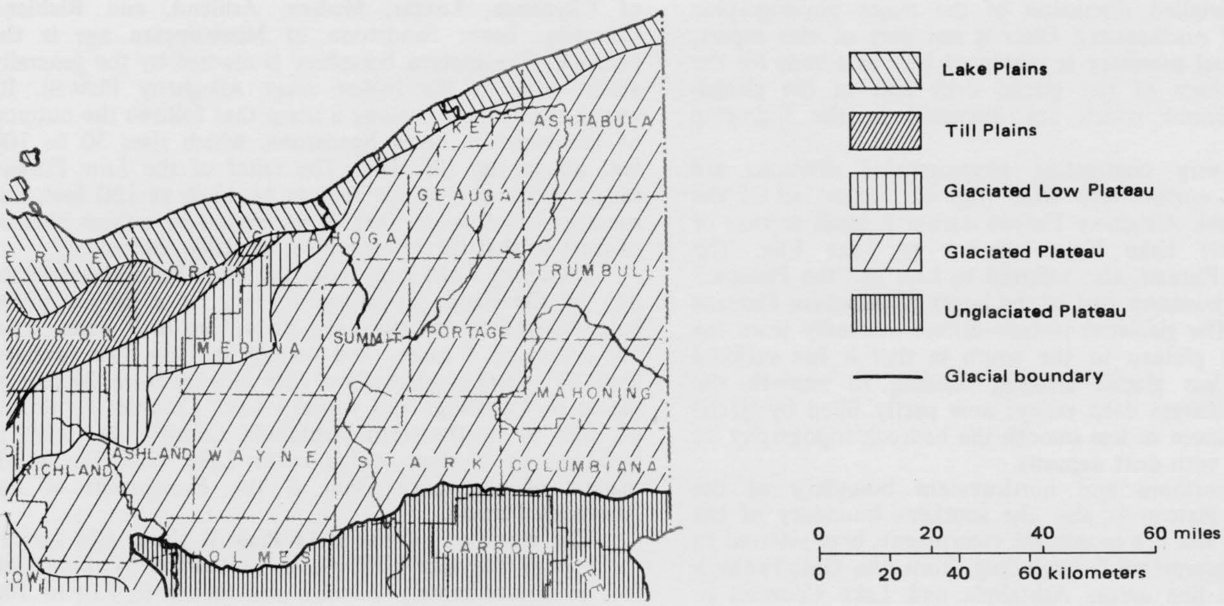


FIGURE 4.–Physiographic divisions in northeastern Ohio.

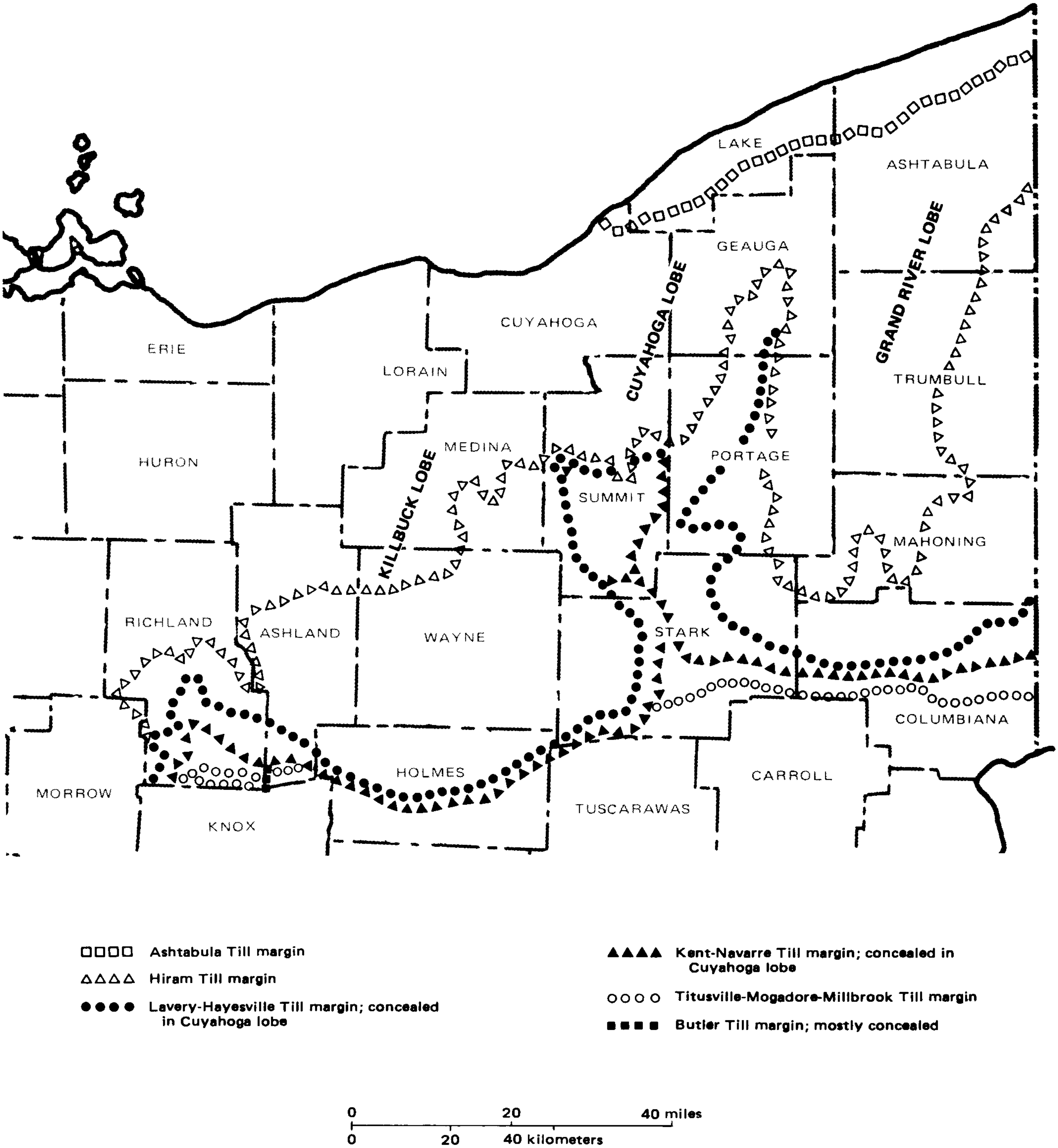


FIGURE 5.–Ice-sheet margins in northeastern Ohio. Lavery and Hayesville margins are approximate owing to the 5 to 10 miles of discontinuous drift extending beyond the continuous drift. A small portion of southwestern Richland County was covered by the Scioto lobe; in this area the Scioto-lobe correlatives of the Millbrook (Jelloway), Navarre (Knox Lake), Hayesville (Mt. Liberty), and Hiram (Centerburg) Tills are present.

More or less parallel to the present lakeshore is a series of sandy and gravelly ridges, which are the beaches of earlier lakes that stood at levels higher than present Lake Erie. These deposits are described in detail in Chapter 5.

GLACIAL LOBES

A description of the glacial lobes is important for the discussion of the glacial deposits of Ohio. Ice sheets in the Pleistocene advanced from a center in Labrador and spread southwest down the Erie basin in an Erie lobe. From the Erie lobe large sublobes, herein called lobes, advanced different distances southward into Ohio (fig. 5).

The Grand River lobe advanced into the highland of the Allegheny Plateau in northwestern Pennsylvania and northeastern Ohio between the higher part of the Plateau near the Pennsylvania-New York state line and the high part of the Plateau in Geauga County, Ohio. The lowland of the wide Grand River valley in Ashtabula and Trumbull Counties, Ohio, served as a funnel to channel the ice selectively toward the western part of the Grand River lobe (White, 1969, fig. 2; White, Totten, and Gross, 1969, fig. 1). The ice of the Grand River lobe advanced as far south as Columbiana and Stark Counties, 75 miles south of present Lake Erie.

The Killbuck lobe advanced west of the Grand River lobe between the Medina-Summit County highland on the east and the western Richland County highland on the west. Ice of this lobe extended as far south as northern Holmes County, about 70 miles south of Lake Erie.

Between the Grand River lobe and the Killbuck lobe a smaller lobe, the Cuyahoga lobe, advanced into northern Summit County in late Wisconsinan (Woodfordian) time.

A large lobe, the Scioto lobe, advanced west of the Allegheny Plateau into the great lowland of central Ohio, which is several hundred feet lower than the Plateau. The ice in this lobe advanced between the Plateau and the highland of the Bellefontaine outlier in Logan County almost to the latitude of Cincinnati (Goldthwait, White, and Forsyth, 1961), more than twice as far south as did the ice on the Plateau. The ice of the eastern margin of the Scioto lobe spilled onto the western margin of the Plateau in southwestern Richland County, Knox County, and counties to the south. As the tills of this lobe are found in such a very restricted tract of the area of this map and report they will be mentioned only very briefly so that correlations can be proposed.

Ice in the Miami lobe advanced southward in the Great Miami River lowland west of the Bellefontaine outlier, reaching the Ohio River (Goldthwait, White, and Forsyth, 1961). The Miami lobe is far west of the Allegheny Plateau and is mentioned here only to complete the picture of glaciation in Ohio.

The tills of the different lobes have been given separate rock-stratigraphic names (see table 2) for reasons explained later.

GLACIAL-EROSIONAL FORMS

At the beginning of the Pleistocene, or glacial time, the northern margin of the Allegheny Plateau was a scarp several hundred feet high, paralleling the southern shore of Lake Erie to about Cleveland and trending southwestward across Cuyahoga, Medina, northern Ashland, and northern Richland Counties, and thence southward to central Ohio. The Escarpment was indented by valleys draining north. South of a major divide across Columbiana, Stark, and Holmes Counties, drainage was to the south and southeast.

The southward advance of the ice more or less coincided with the grain of the area, so that the advancing ice was funneled into the lower areas between the higher divides of resistant sandstone of Mississippian and early Pennsylvanian age. The advance of the ice deepened the lowlands, especially where the lowlands coincided with the direction of ice advance. The deepened valleys are an important feature of the bedrock surface and of much of the present landscape. The valleys are even more impressive when it is realized that they are as much as several hundred feet deeper than they appear on the surface, because they are partly filled by glacial drift (see fig. 9). The location of these valleys is in some part evident on plate 1; they are now sites of outwash (valley trains), floodplains (alluvium), kame terraces, or some combination of these. The major buried or partly buried valleys are the locations of preglacial or interglacial streams on the various maps of Stout, Ver Steeg, and Lamb (1943) and the map of Cummins (1959). More recent data provide modifications of the time at which some of the valleys were cut, and further revisions will be made in the future as more subsurface geological investigations are made.

Rock hills were molded into rounded oval forms by the advancing ice. These hills are especially well displayed in northeastern Medina, Summit, and Geauga Counties. In these areas the drift is very thin and bedrock crops out in many places. The oval shape of the ground-moraine map pattern on plate 1 in these high areas is evidence of the underlying rounded bedrock hills.

The effect of glacial erosion was to remove some of the bedrock and incorporate it in the advancing ice. Hundreds of feet of bedrock were removed in some valleys, but much less was eroded from the uplands. Erosion of bedrock was more common with the earlier ice sheets, the deposits of which are notably sandy and coarse. The later ice sheets, Lavery and Hiram, eroded very little of the bedrock; they chiefly eroded the silty, clayey materials in the lowlands.

In addition to the shaping of the bedrock, glacial erosion took place on earlier till deposits. As the later ice sheets advanced, earlier till was eroded, removing either much of the till or only part or all of the soil that had formed on the earlier deposits.

Stream erosion in interglacial and interstadial times was significant at places and, although not strictly glacial erosion, should be mentioned. Stream erosion is particularly important where interglacial or interstadial channels were filled with sand or gravel and covered by later till deposits. Examples are cited later in the discussions of the Sangamonian Stage and the Farmdalian Substage. The economic importance of the buried sand and gravel is discussed in Chapter 7.

The great valley of the Grand River in western Ashtabula County and northwestern Trumbull County is a prominent feature. It consists of an inner valley about 30 miles long and about 3 miles wide. The bedrock bottom of the valley is below 600 feet in elevation and more than 600 feet below the highest point on the upland to the west. The valley is now filled by drift to an elevation of 800 feet. On the east side of the deeper valley is a bench as much as 5 miles wide at an elevation of about 900 feet. Together, the inner valley and the bench form the 8-mile-wide Grand River Lowland, which guided ice from the main Erie lobe into the Grand River lobe.

Chapter 3

GEOMORPHOLOGY OF THE GLACIAL DRIFT

The surface form of the glacial deposits is controlled by the varying character of the material, the mode of deposition, and the character of the underlying surface bedrock or earlier drift.

The glacial drift of northeastern Ohio was deposited directly by the ice or by running water derived from melting ice. The ice-laid material, or till, is an unsorted mixture of clay, silt, sand, pebbles, and cobbles. The texture and mineral content of the till sheet deposited by one ice advance is quite constant, even over a wide area, but the texture and mineral content of one till sheet may be quite different from another. The meltwater-deposited material, or outwash, is more or less sorted and deposited in layers; these deposits are stratified and composed of sand and gravel. The finest materials, silt and clay, may be carried to temporary lakes; such deposits are fine grained and the layers are very thin. Each type of deposit has a characteristic topographic form.

The variation in topography (smooth or hummocky), the variation in thickness, and the variation in composition all contribute to a great variety of environmental conditions. Foundation conditions, drainage, slope stability, and other engineering features may be favorable for gravel and sand operations, water supply, or liquid- or solid-waste disposal. An understanding of the glacial features is necessary for planning the use of the glacial resources.

GROUND MORAINE OR TILL PLAIN

A great expanse of till was deposited as a more or less uniform sheet covering the bedrock as ground moraine (pl. 1). Where the bedrock surface is reasonably level, the surface of the till cover is smooth to gently undulating. Where the bedrock surface has more relief the till cover produces a masked erosional topography. If the relief is pronounced, the bedrock may be exposed on the surface or on hill slopes, especially in areas of older drift where more postdepositional erosion has taken place.

The largest continuous area of ground moraine is in Ashtabula, Trumbull, northern Mahoning, northeastern Stark, eastern Portage, Geauga, part of Cuyahoga, northern Medina, and southern Lorain Counties. This area in general is an area of younger till—Lavery and Hiram—with high clay and silt content. The area is level to slightly undulating, with a relief of 10 to 30 feet per mile, and is generally moderately to poorly drained. In Richland, Ashland, southern Medina, and northwestern Wayne Counties in the Killbuck lobe, linear end moraines divide the ground moraine into belts.

In the more hilly part of the glaciated area in northeastern Ohio the ground moraine between the deeper valleys may be quite level, as in northern Summit County and elsewhere, but these rather level areas are generally not more than 1 to 5 miles wide. Along the hillsides the ground moraine is of varied thickness and topographic expression. The drift thickness in areas of ground moraine may be less than 10 feet and is seldom more than 20 feet.

END MORAINES

End moraines form along the margins of ice sheets, generally at a time of readvance and marking the limit of that advance. The end moraines are continuous belts of hummocky topography and commonly can be traced across a large area.

Leverett (1902) named many of the moraines in Ohio for cities and villages located on them. The origin of the names for the moraines, those given by Leverett as well as others, is outlined in Totten (1969). Leverett traced the moraines in great detail on the ground because he had few or no topographic maps at that time; his work still contains the most elaborate descriptions of the moraines. Some revision (Goldthwait, White, and Forsyth, 1961) of Leverett's mapping was possible from complete topographic map coverage, mainly at a scale of 1:62,500. Detailed studies of more recent 1:24,000 maps and of air photos enabled Totten to map the moraines in Crawford, Huron, and parts of Richland and Ashland Counties with more precision. Totten's (1969) study led to a revision in some of the moraine correlations shown on Leverett's map (1902) and the map of Goldthwait, White, and Forsyth (1961).

The end moraines in northeastern Ohio do not record the margin of the last ice sheet, but, as shown by Totten (1969), they were formed by an earlier ice sheet that was more heavily laden with debris than the later ice sheets. Later ice advances passed over the end moraines, leaving a thin veneer of drift over the earlier ridges. In some cases the margin of a later advance did coincide with an end moraine, but it was not this later advance and halt that built the major mass of the moraine; the moraine was the already-present barrier that controlled the later advance.

The moraines are shown on plate 1 and figure 6. Both maps show that the individual moraines are in contact and combination with one another as they cross the ancient valleys at Savannah in northwestern Ashland County, at Lodi in southern Medina County, and the valley now occupied by West Branch Rocky River and River Styx just southeast of Medina, Medina County. In the valleys the moraines cannot be separated, and the pronounced hummocky topography in which kames are prominent is bewildering.

In northeastern Medina County and much of adjacent northern Summit County the high bedrock hills are separated by deep bedrock valleys. In this area the end moraines form a mass of knolls and kettle holes, and no separate ridges can be identified.

A prominent feature of northern Richland, northern Ashland, extreme northwestern Wayne, and southern Medina Counties is a series of linear ridges of hummocky topography that rise 10 to 50 feet or more above the ground moraine. A single ridge occurs in southern and eastern Cuyahoga, Geauga, Trumbull, and southeastern Ashtabula Counties (pl. 1; fig. 6). These discrete hummocky ridges are in contrast to hummocky topography without linear trend common along valleys south of the end moraines.

The Lake Escarpment moraines of extreme northeastern Ohio (Ashtabula, Cuyahoga, and Lake Counties) are quite different from those discussed so far. They were deposited along the Escarpment at the margin of the Lake Plain east of Cleveland. Their deposition was controlled by a simple pronounced bedrock feature, the Escarpment, which accounts for their position and extent. These moraines are discrete, prominent features and are easily identified throughout their course; the type localitites for the Lake Escarpment moraines are within Ashtabula, Cuyahoga, and Lake Counties.

Inspection of the glacial map of Ohio (Goldthwait, White, and Forsyth, 1961) shows that the end moraines of the till plain in central and western Ohio are widely spread and separated by ground-moraine belts several miles wide. In contrast, the end moraines on the Allegheny Plateau of northeastern Ohio are much closer together or in contact. End moraines in central Ohio are spread over a north-south distance of about 100 miles, whereas north from Mansfield in the western part of northeastern Ohio the distance is barely 20 miles, and north from Ashland it is only 14 miles. Northeast of Medina along the side of the upland east of the West Branch Rocky River valley, end moraines are crowded into an area barely 5 miles wide. Still farther east in Summit County the end moraines are no longer discrete features (except the Defiance Moraine), and the drift is in confused masses of hummocky topography between high bedrock hills. Thus, except for the most northerly end moraine, the Defiance Moraine, individual end moraines cannot be traced east of Medina County.

Correlation of the moraines becomes increasingly difficult eastward because ice movement was retarded by the higher land of the Plateau. The margin of each moraine-building pulse was therefore much closer to the previous one, and they sometimes coincided. Another factor hindering orderly moraine deposition on the Plateau is the bedrock relief, which may be several hundred feet. Most traceable end moraines (single ridges) end in valleys where several moraines join in a mass of hummocks and depressions. One of the best examples is the West Branch Rocky River valley in Medina County, although here, unlike valleys farther east in Medina and Summit Counties, some correlation can be made of more or less discrete moraines beyond the valley. The only exception is the Defiance Moraine, which maintains its beltlike character as it descends and crosses valleys. Correlation problems also can be attributed to the irregular retreat of the ice in rugged areas on the Plateau. The ice thickness in the waning stage was so variable, thicker in the valleys and thinner or quite dissipated over the hilltops, that the forward motion required to maintain an ice front along which an end moraine could be built ceased, the ice stagnated, and deposits were heaped irregularly around the ice blocks. A hummocky topography was produced, like the hummocky topography of end moraines. Meltwater irregularly deposited sand and gravel along with the till in these areas. This hummocky topography without linear trend is differentiated from the hummocky topography of the end moraines on plate 1.

JOHNSTOWN MORAINE

The Johnstown Moraine passes northward out of the Scioto lobe from Morrow County to enter the southwestern corner of Richland County, whence it turns northeast. Just north of Mansfield it takes an easterly course to the eastern part of Richland County, where it becomes narrow and can no longer be traced. The Johnstown Moraine ranges in width from 1 to 3 miles as it traverses a region of greater bedrock relief than the moraines to the north. Its ridgelike character is not as evident as that of the other moraines.

POWELL MORAINE

The Powell Moraine enters Richland County from the eastern side of the Scioto lobe and takes a northeasterly course to the eastern margin of the county. A ridge ½ mile wide and about 2½ miles long west of Ashland, Ashland County, is the easternmost vestige of the Powell Moraine. In Richland County the Powell Moraine ranges in width from ½ mile in the southwest to 1¼ miles west of Mansfield, increasing to 2 miles at the Black Fork valley northeast of Mansfield. The Powell Moraine is separated from the Johnstown Moraine by a very narrow belt of ground moraine.

BROADWAY MORAINE

The Broadway Moraine enters Richland County from Crawford County and passes northeast and thence east across Richland County. It is made up of discontinuous patches for about 6 miles in west-central Richland County rather than being a continuous ridge. However, in western Ashland County the Broadway Moraine is more continuous as far as the Jerome Fork valley in the central part of the county, where it joins the more massive Mississinewa Moraine on the north. The joined moraines form a confused hummocky morainic complex in the valley of Jerome Fork, and the Broadway Moraine cannot be traced farther east.

MISSISSINEWA MORAINE

The Mississinewa Moraine is a complex series of ridges, in places separate and in others closely packed together. This is sometimes called the Mississinewa system. This moraine enters Richland County from Crawford County and extends from Shelby, Richland County, to the Black Fork valley as three separate ridges. East of that valley, the moraine is composed of several ridges, ¼ to 1 mile wide, which continue into Ashland County to the deep ancient valley now occupied by Jerome Fork. The Jerome Fork valley is choked by a mass of hummocky drift deposits where the Broadway, Mississinewa, and St. Johns Moraines join. West of the Jerome Fork valley the separate ridges of the Mississinewa Moraine form a complex of very hummocky topography in which the separate elements hardly can be distinguished. From eastern Ashland County a conspicuous ridge of morainic topography about 2 miles wide continues into the northern part of Wayne County for 12 miles to

Creston. This moraine was formerly called the Wabash Moraine (White, 1967, p. 4), but Totten (1969) showed that the Wabash Moraine lies farther north. At Creston the Mississinewa Moraine is joined by the Wabash Moraine and is overridden by it. North of Seville, Medina County, a morainic ridge bends around the highland between the Chippewa Creek valley and the River Styx valley. East of the latter valley a prominent ridge extends north past Windfall (a crossroad 5 miles east of Medina). This ridge becomes a composite moraine north of Windfall. These ridges east and west of the River Styx are tentatively correlated with the Mississinewa Moraine.

ST. JOHNS MORAINE

The St. Johns Moraine enters the northwestern part of Richland County from Crawford County and passes eastward across Richland County into extreme western Ashland County north of Savannah. Northeast of Savannah the St. Johns Moraine is the middle part of the wide complex of pronounced morainic topography formed by the Mississinewa Moraine to the south and the Wabash Moraine to the north. In eastern Ashland County the St. Johns Moraine disappears beneath the Wabash Moraine and cannot be traced farther east. East of the Savannah complex the St. Johns Moraine cannot be traced as a separate entity, but the southern part of the Wabash Moraine as far as the Ashland-Wayne County line may represent the St. Johns Moraine.

WABASH MORAINE

The Wabash Moraine enters northwestern Richland County from Crawford County and passes northeastward for 5 miles, whence its course becomes eastward across northern Richland and southern Huron Counties into northwestern Ashland County. It extends eastward to north-central Ashland County as a part of the Savannah morainic complex in the ancient valley now occupied by Jerome Fork. In the eastern part of the county it is again traceable as a separate linear belt of well-displayed morainic topography. It is separated from the Fort Wayne Moraine on the north by a belt of ground moraine about ½ mile wide. In the central part of its course across Ashland County the morainic tract is about 1½ miles wide, and the southern part appears to include the St. Johns Moraine, which does not extend eastward into Wayne County. Along the Wayne-Medina County line the Wabash Moraine extends for almost 6 miles as a single belt about 2 miles wide. In the Wayne County report (White, 1967, p. 3) this belt was identified as the Fort Wayne Moraine. The Fort Wayne Moraine on the north joins the Wabash Moraine just north of the Wayne-Medina County line, and the combined moraines continue eastward to the lowland south of Lodi, Medina County. There the Wabash Moraine separates from the Fort Wayne Moraine and continues east through Burbank, Wayne County, for 5 miles east to Creston, Wayne County, as a great area of kames and outwash in which many large gravel pits are present. This stretch of moraine shows very clearly that the bulk of the moraine is composed of Millbrook Till and associated gravel. Only a thin veneer of clayey silty Hayesville and Hiram Tills and discontinuous sandier Navarre Till is present.

At Creston the Wabash Moraine joins the Mississinewa Moraine from the south, and the joined moraines continue northward along the eastern margin of the kame and outwash area to the adjacent Chippewa Creek valley, which was dammed by the moraine. Present-day Chippewa Lake is the last remnant of a once larger lake. The combined Wabash-Mississinewa Moraines pass northward for 5 miles along the upland east of the Chippewa Creek valley, turn abruptly east, and divide into two prominent ridges. The more southerly ridge is correlated as the Mississinewa Moraine, the other as the Wabash Moraine. The Wabash Moraine along with the Fort Wayne Moraine turns east and southeast to the ancient valley of River Styx, which is choked by a confused moraine complex forming the divide between the north-flowing West Branch Rocky River and the present south-flowing River Styx. From the River Styx valley the ridge extends north between Sharon Center and Boneta, Medina County, and is joined on the east by the Mississinewa Moraine. Here the ridge, correlated with the Wabash Moraine, continues north to a point about 2 miles southeast of Brunswick, Medina County, whence the ridge turns east, continuing almost to Hinckley. It cannot be traced farther.

FORT WAYNE MORAINE

The Fort Wayne Moraine crosses the extreme northwestern corner of Richland County as a belt of morainic topography less than ½ mile wide. It passes into Huron County, becomes as much as 2 miles wide, and crosses the southern part of that county to enter Ashland County just southwest of Ruggles. Across the 4-mile-wide lowland that occupies most of Ruggles Township, the moraine is missing. The origin of this lowland is not yet understood. The southern boundary of this lowland is the Savannah complex of very hummocky morainic topography where the Mississinewa, Wabash, and St. Johns Moraines form a confused area for 10 miles southeast of the lowland in the ancient valley now occupied by Jerome Fork. East of the lowland the Fort Wayne Moraine is again evident, and across north-central and northeastern Ashland County, from west of Nova to east of Sullivan, the Fort Wayne Moraine is in two separate ridges. In Medina County southwest of Homerville the ridges join, and a single ridge extends eastward for 6 miles to the lowland south of Lodi, joining the Wabash Moraine on the south.

The Fort Wayne Moraine is absent for 3 miles in the lowland south of Lodi, but reappears at Lodi on the northeast side of the lowland and continues north and northeast and thence east and southeast to Chippewa Lake. East of Chippewa Lake the moraine extends north and thence east around the highland east of the ancient Chippewa Creek valley to the confused complex of hummocky morainic topography in the Rocky River valley at Medina. North from the Rocky River valley the Fort Wayne Moraine may be part of the morainic tract that extends 10 miles north past Windfall and Weymouth, but no part of this tract can be positively identified as Fort Wayne.

NEW WASHINGTON MORAINE

The New Washington Moraine extends across southern Huron County past New London, where it bends southeast to enter Ashland County in the extreme northwestern corner. It bends east across extreme northern Ashland County in a gentle arc; its south margin is followed on the west by a west-flowing tributary of the Vermilion River and on the east by the east-flowing West Fork of East Branch Black River. The moraine across Ashland County is about a mile wide. At the Ashland-Lorain County line north of Nova, the New Washington Moraine is joined and then overridden by the Defiance Moraine from the north. This may account for the increased bulk and prominence of the Defiance Moraine in western Medina County.

Six miles west of Medina the New Washington Moraine reappears from beneath the Defiance Moraine and extends through Medina and thence southeast for 4 miles to the filled ancient valley now occupied by the headwaters of West Branch Rocky River. Although it cannot be identified in the complex morainic belt that trends northward on the east side of the ancient valley, the New Washington Moraine may make up part of this complex.

DEFIANCE MORAINE

The Defiance Moraine is the only end moraine that can be traced completely across Ohio (Cushing, Leverett, and Van Horn, 1931, fig. 8). The Defiance Moraine enters southern Lorain County and northern Ashland County from Huron County as a massive ridge more than 2 miles wide. It joins the New Washington Moraine on the south to form a single massive ridge 1 to 2 miles wide as far as Lodi. The moraine east of Ashland County is regarded entirely as Defiance Moraine, which has overridden the New Washington Moraine. The southern margin of the moraine is marked by West Fork of East Branch Black River as far as Lodi.

In southwestern Medina County the southeastern course of the moraine is influenced by the western slope of the great ancient valley of East Branch Black River. The eastern slope of this ancient valley controls the continuation of the moraine due northward from Lodi for 7 miles past Chatham. Beyond Chatham the Defiance Moraine turns eastward around the highland between East Branch Black River and the ancient Chippewa Creek valley and thence turns southeast to cross the northern part of the Chippewa Creek valley, where it completely blocks the valley. The Defiance Moraine extends northeast around the highland between the Chippewa Creek valley and the ancient West Branch Rocky River valley.

A southern element of the Defiance Moraine diverges from the main moraine in Medina County at the Chippewa Creek valley west of Medina; the city of Medina is located on this branch. This element may represent the re-emergence of the New Washington Moraine from beneath the Defiance Moraine. The branch trends southeast from Medina to the valley of West Branch Rocky River, where it enters the confused morainic complex that fills the valley for 10 miles. This complex is made up of Wabash, Fort Wayne, and perhaps other moraines.

From the West Branch Rocky River valley the moraine extends northeast along the upper slope of a highland, past Brunswick, and thence east along the Cuyahoga-Medina County line to the wide ancient valley (now East Branch Rocky River) south of North Royalton and thence north along the upper slope of the highland. The moraine then turns east-southeast through Broadview Heights and Brecksville, where its northern margin is marked by Chippewa Creek (not the Medina and Wayne County Chippewa Creek). Southeast and east of Brecksville the moraine loops the Cuyahoga River valley. Its course is east and south from along the upper part of the west side of the valley for 8 miles to Peninsula in northern Summit County, whence it crosses the valley and passes north along the east side for 16 miles to Warrensville Heights, Cuyahoga County. The Defiance Moraine then takes a southeasterly course to Chagrin Falls, crosses the Chagrin River valley, and ascends the slope of the Geauga County highland for 16 miles to Hamden. The moraine continues east, southeast, and south along the east side of the highland, which is also the west side of the Grand River Lowland.

The loop around the major part of the Grand River Lowland is a very distinctive feature that shows the delicate topographic control of the ice-sheet margin that deposited the moraine. The loop, 24 miles across, extends from northeastern Geauga County to central Trumbull County to southeastern Ashtabula County. The north-south dimension is about 28 miles. The moraine on the west side of the loop in Geauga County is a distinctive ridge, in places divided into two ridges with a total width of 2 miles or more. Across the south end of the loop in Trumbull County the 1- to 2-mile-wide ridge is a distinctive feature, well shown at the Mosquito Creek Reservoir dam, which is constructed across the valley at a narrow place where Mosquito Creek cuts through the moraine. Northward from Mosquito Creek the moraine is a well-marked single ridge along the east side of the Grand River Lowland. In northeastern Trumbull County the moraine is composed of two ridges, which continue into Ashtabula County, where the moraine turns to the northeast past Andover to enter Pennsylvania east of North Richmond.

SPENCER MORAINE

The Spencer Moraine is a distinct morainic ridge in southeastern Lorain County and northwestern Medina County. West of East Branch Black River the Spencer Moraine is 2 to 3 miles north of the Defiance Moraine, but east of that valley it approaches the Defiance Moraine, and south of Lester, northwest of Medina, it joins the Defiance Moraine and can no longer be traced. It may form part of the Defiance Moraine north of Medina. In Medina County east of East Branch Black River an unnamed stream marks the southern border of the Spencer Moraine.

SUMMIT COUNTY MORAINIC COMPLEX

The area of sharp knolls and depressions in northern Summit County and northeastern Medina County cannot be separated into individual end moraines (pl. 1; fig. 6). The successive ice margins that formed the end moraines older than the Defiance Moraine thrust southward in a small Cuyahoga lobe in northern Summit County and extreme northeastern Medina County. At various times they occupied the space between Akron on the south to an irregular line 5 to 8 miles north. Thus the successive marginal deposits here were confined to a belt not more than 8 miles wide, whereas the successive margins were spread out over a space of 20 miles in Richland and Huron Counties and over 40 miles farther west in the Scioto lobe. In addition, the bedrock and premorainic topography was one of hills and valleys with several hundred feet of relief, contributing to irregular ice margins and to isolation of separate ice blocks at each stage of retreat. Meltwater deposited gravel near the ice blocks so that the drift of the region has a high percentage of gravel and is in part kames. After the deposition of this great mass of coarse material, later ice advances deposited a more or less thin cover of clayey and silty till.

The surface of this area consists of sharp knolls and depressions; lakes and ponds are present in some of the depressions. Some bedrock hills extend above the hummocky surface; their surfaces are only thinly covered by till and are mapped as smoother ground-moraine islands within the hummocky area.

In Stow, in extreme eastern Summit County, the great moraine tract joins the massive Kent Moraine on the west side of the Grand River lobe.

KENT MORAINE

The Kent Moraine is very different from the end moraines so far described (except for the Summit County complex). It is not a single discrete belt or ridge, or several ridges, but a wide irregular belt of very hummocky topography with many kames; the Kent Moraine has such a high proportion of kames that it is properly called a kame moraine. The Kent Moraine ranges in width from about 5 miles to almost 15 miles. The great bulk of the moraine was formed by the Titusville ice sheet of Altonian age, but there are considerable additions of Kent Till in part of the moraine. Younger Lavery and Hiram Tills are present in part of the moraine but, except in south-central Geauga, northwestern Portage, and eastern Summit Counties, add little to the bulk of the moraine.

The Kent Moraine could very properly be called the Kent Moraine Belt, but as the name Kent Moraine has been previously used in Ohio (Goldthwait, White, and Forsyth, 1961; Winslow and White, 1966, p. 28) and Pennsylvania (White, Totten, and Gross, 1969, fig. 2; Shepps and others, 1959, p. 31, pl. 1) the name also will be used here.

Unlike the end moraines already described, the Kent Moraine does not mark a sharp ice margin where the ice advanced to a line and fluctuated over a narrow belt to form a single ridge or closely spaced discrete ridges. The marginal ice stagnated in a belt ranging up to 15 miles wide, and masses of till and gravel were deposited in a confused mass around ice blocks, in holes and low places in the ice, and on top of the dissipating ice. Perhaps some pulses of active ice advanced into the marginal area, but lines of such advance have not been identified. The present surface is therefore made up of sharp knolls and depressions. The later advance of the Kent ice sheet retreated in the same way, but that ice carried, in most places, much less drift than did the earlier Titusville ice.

The Kent Moraine enters Ohio from Pennsylvania in southeastern Mahoning County and northeastern Columbiana County, where it is 12 miles wide. In many places across Mahoning and Columbiana Counties higher rock hills extend above the moraine and are areas of ground moraine within the end moraine (pl. 1; shown in part in fig. 6).

In central Stark County the moraine curves to the north at Canton. Northward into Summit, western Portage, and Geauga Counties the Kent Moraine assumes the character of a kame moraine, and only the eastern part is composed of till knolls. In the northwestern part of Canton the Kent Moraine approaches the strong morainic topography of the east side of the Killbuck lobe and only the narrow valley of West Branch Nimishillen Creek divides the Kent Moraine from the Buck Hill Moraine as far as the Stark-Summit County line.

BUCK HILL MORAINE

On the east side of the Killbuck lobe in southwestern Summit and western Stark Counties is a tract of very hummocky topography similar to that of the Kent Moraine. This moraine will be described as the Buck Hill Moraine, named for a very prominent feature in the western part of Canton.

The Buck Hill Moraine begins near the bend of the Tuscarawas River at the Tuscarawas-Stark County line 5 miles east of Beach City and extends east and north for almost 7 miles as a ridgelike feature 1 to 2 miles wide. Here it closely approximates the form of the true end moraines much farther north. The Buck Hill Moraine coincides with the glacial boundary for several miles. The moraine is almost entirely till as far as western Canton, where the till gives way to kames. Buck Hill, formerly at the western margin of Canton but now within the city, was a very prominent elongate kame that is now almost completely removed by gravel operations. Buck Hill was so striking that Newberry (1874, p. 44; see figure 7 of this report) used a cross section of it to illustrate kame structure. This is the earliest diagram of a kame in Ohio, and probably in North America.

The Buck Hill Moraine becomes much wider at Canton and increases to 5 miles in width just northwest of Canton and to 10 miles in width in northern Stark County. At McDonaldsville, Stark County, a highland area of ground moraine 5 miles long in an east-west direction and up to 2 miles wide in a north-south direction extends above the moraine.

The Buck Hill Moraine has an east-west trend in southwestern Summit County and extends as a narrow belt less than a mile wide on the north side of the Chippewa Creek valley from Clinton, Summit County, westward to a point 5 miles south of Doylestown, Wayne County. It was formed by ice of an eastern protrusion of the Killbuck lobe as far as the West Branch valley in central Stark County. In northwestern Stark and southwestern Summit Counties the ice was actually moving north.

In southwestern Summit County east of Clinton and south into Stark County the Buck Hill Moraine consists almost entirely of rugged kames, some as much as 100 feet high. This topography is similar to that of the Kent Moraine to the east. North of the Summit-Stark County line the Buck Hill Moraine has the same characteristics as the Kent Moraine. It is composed mainly of kames, but with some areas of hummocky till.

From just north of Canton to the Stark-Summit County line the east margin of the Buck Hill Moraine is drawn at the west side of West Branch valley, and the western boundary of the Kent Moraine is drawn along the east side of the valley, with a narrow valley train separating the moraines. The distinction between the two moraines is only arbitrarily drawn from Aultman, on the Stark-Summit County line, for 7 miles north to the northeastern limit of the Buck Hill Moraine. Indeed, in most of southern Summit County the Buck Hill and Kent Moraines form a continuous area of kame-moraine topography and may be regarded as an interlobate area.

The topography of the Buck Hill Moraine from Canton north is one of pronounced kames and kettle holes. Many lakes are present in the kettle holes; the most prominent are the well-known Portage Lakes.

On figure 6 the Buck Hill Moraine is not shown extending to Beach City. As may be seen on plate 1, irregular tracts of hummocky topography do continue westward around the outer 4 to 8 miles of the Killbuck lobe. However, these tracts are smaller and far more irregular than those of the Kent Moraine or the Buck Hill Moraine east of the Tuscarawas River. They are generally confined to valleys and are associated with kame terraces in the valleys rather than with kames in and below the hummocky tracts.

LAKE ESCARPMENT MORAINES

Leverett (1902, p. 651) used the term "Lake Escarpment Moraine" to describe "a system of moraines which covers part of the brow and much of the face of the Lake Erie escarpment from near Cleveland, Ohio, eastward into New York." These moraines are closely spaced, but not in actual contact, and are very prominent features, especially east of western Lake County. They provide a great contrast to the flat Lake Plain to the north and, especially in Ashtabula County, to the level Plateau to the south. The moraines provide attractive home sites because the drainage is better than that to the north or the south and the cores of some of the moraines are gravelly and thus excellent sources of ground water.

Euclid Moraine

The Euclid Moraine extends from Euclid, 10 miles east of Cleveland, across Lake County and most of Ashtabula County. It lies along the margin of the Escarpment at Euclid but diverges from the Escarpment in most of its easterly course. The Euclid Moraine is a ridge less than 1 mile wide from Euclid to the Grand River near Painesville in Lake County, but east of that point it is from 1 to 1½ miles wide as far as the great bend of the Grand River at Austinburg, western Ashtabula County. There are several discontinuities in the moraine where the Chagrin River and the Grand River have cut through it. Southwest of Austinburg the continuous moraine becomes wider and then is absent for 2½ miles across the Grand River depression south of Austinburg. East of the Grand River Lowland the Euclid Moraine continues as two ridges less than ½ mile wide separated by the valley of Center Creek.

The southern ridge ends south of Sheffield Center, Ashtabula County, but the northern ridge continues to just west of Kelloggsville. East of Kelloggsville two small morainic patches represent the extreme eastern end of the northern element of the Euclid Moraine. Leverett (1902, p. 653, pls. 15, 18) believed the Euclid Moraine extended for 6 miles into Pennsylvania, but he did not have the advantage of topographic maps or air photos. Later mapping (Shepps and others, 1959) showed that the moraine does indeed fray out in eastern Ashtabula County, and does not extend across the state line.

The surface of the Euclid Moraine west of the Grand River is very hummocky, with some knolls as much as 30 feet high. The moraine exhibits a very prominent undulating crest about ¼ mile from the southern margin. East of the Grand River the moraine is lower and hummocks are much less prominent, especially in the southern ridge. However, the eastern part of the northern ridge has several prominent kamelike knolls as much as 40 feet high.

The Euclid Moraine in Ashtabula County lies upon the Plateau and is south of the bedrock escarpment. The drift composing the moraine ranges in thickness from less than 20 feet to as much as 50 feet in places and is composed of several tills. The youngest till, the Ashtabula Till, is thin and discontinuous and overlies clayey Hiram and Lavery Tills. A core of Titusville Till of Altonian age is probably present, but good outcrops to show this are lacking. In the northern element of the Euclid Moraine northwest of Sheffield Center, buried kame gravel of probable Titusville age crops out at a few places.

Painesville Moraine

The Painesville Moraine extends from the Cuyahoga-Lake County line across Lake and Ashtabula Counties. The northern margin of the moraine is at the southern margin of the Lake Plain as far east as Saybrook, Ashtabula County. At places along the western part of its course, shore erosion by glacial Lake Maumee (or an even earlier predecessor of Lake Erie) has cut into the moraine at an elevation of about 780 feet, very much reducing its width and indeed cutting through it at some places (pl. 1; fig. 6). From Madison, Lake County, eastward across Ashtabula County, the Painesville Moraine is 1½ to 2½ miles wide, much wider than to the west. From Ashtabula eastward the Ashtabula Moraine lies north of the Painesville Moraine, and Hubbard Run, the Ashtabula River, and Conneaut Creek flow in the depression between these moraines.

The southern margin of the Painesville Moraine as far as Painesville is along a narrow depression between it and the Euclid Moraine on the south; the southern margin from Painesville to Austinburg is the valley of the Grand River. From Austinburg to Plymouth Center, the southern margin is at the Grand River Lowland and its eastward extension; the moraine rises conspicuously above the lowland. From Plymouth eastward the southern margin of the moraine is at the Ashtabula River, and farther east is at Ashtabula Creek.

The surface of the Painesville Moraine is markedly hummocky, with hummocks up to 30 feet high. The most conspicuous hummocks are in eastern Lake County and in Ashtabula County; they are arranged in a ridgelike line ¼ to ⅝ mile north of the south margin, where the moraine reaches an elevation of 865 feet on the west. The ridge elevation gradually increases to as much as 930 feet on the east. Some of the prominent ridges within the moraine may be thrust sheets. Some of the high hummocks are kames which are almost completely buried, but whose tops are exposed.

The Painesville Moraine lies along the upper part of the slope of the bedrock escarpment. It is noteworthy that, unlike the Euclid Moraine, the Painesville Moraine passes across the ancient valley of the Grand River at Austinburg and completely fills it. Here the Grand River, which flowed north for 25 miles, was forced to turn westward at right angles and flow in a very narrow valley, which is a gorge between the Painesville Moraine and the Euclid Moraine to the south. The thickness of the drift is at least 250 feet in the filled valley at Austinburg. Elsewhere, the drift of the moraine ranges in thickness from 30 feet to more than 100 feet. The upper part of the moraine is composed of Ashtabula, Hiram, and Lavery Tills of Woodfordian age. The lower part is composed of Titusville Till of Altonian age and is in part very gravelly. Keefus Till and earlier tills of probable Illinoian age have been noted in the buried valley at Austinburg.

Ashtabula Moraine

The Ashtabula Moraine extends from Ashtabula eastward into Pennsylvania. It lies along the lower (northern) part of the bedrock escarpment. The moraine appears to have extended northwest of Ashtabula and to have been cut off by wave erosion of glacial and postglacial lakes. The moraine has been eroded into discrete fragments from ¼ to 1 mile long from Ashtabula to Kingsville. Erosion on the outside of meander bends of the Ashtabula River has cut through the moraine at several places from the south, and wave erosion of glacial Lakes Maumee and Whittlesey has removed much of the moraine on the north. At Kingsville a gap 1¾ miles wide, with only a tiny remnant of the moraine preserved as the hill in the center of the village, was created by a combination of lake erosion and of stream erosion by Conneaut Creek. This creek entered Lake Maumee and later Lake Whittlesey at a location as much as a mile west of the present reverse bend of the stream where it changes its westward course to an eastward direction. This gap is the site of a composite of delta and beach-gravel deposits.

East of Kingsville the moraine is very narrow for about 2 miles because of wave erosion on the north and stream erosion on the south. Farther east the moraine is 1¼ to 1½ miles wide. It is bounded on the south by the gorge of Conneaut Creek and on the north by the Whittlesey beach at an elevation of 740 feet. At a few places small benches at elevations of 760 to 770 feet record Lake Maumee erosion.

The moraine crest rises from 800 feet in southwest (Ridgeview Burial Park) and southern (Knollwood) Ashtabula to 820 feet near Kingsville to 860 feet at the Ohio-Pennsylvania state line. The surface is hummocky, with some knolls as much as 30 feet high. Some of the higher knolls are kames within the moraine; these kames are excellent sources of ground water.

South of Conneaut the moraine consists of closely spaced parallel ridges. These ridges may be thrust sheets, as described for the ridges of the Painesville Moraine.

The surface till of the Ashtabula Moraine is Ashtabula Till, at places of considerable thickness. The underlying material is earlier till, and in places buried kames provide gravel of considerable thickness.

HUMMOCKY TOPOGRAPHY WITHOUT LINEAR TREND

In the Plateau south of the definitive end moraines of the Killbuck and Cuyahoga lobes and in the Grand River lobe between the Defiance Moraine and the Kent Moraine, tracts of hummocky topography exist. These tracts do not have a linear trend and are interpreted as deposits of a waning ice sheet that had lost most or all of its forward motion. These tracts are generally at lower elevations along valley sides or in valleys that are more or less filled.

The complexity of the outline of these hummocky tracts can only be indicated in a general way on plate 1. It would be tedious to describe these tracts in detail, but some general observations may be made. In the Grand River lobe the irregular areas of nonlinear hummocky topography north of the Kent Moraine are in general smaller and less common than those in the Killbuck lobe.

One of the most continuous tracts of hummocky topography in the Killbuck lobe is in southern Richland County and extends from Mansfield for 8 miles southeast beyond Little Washington. Near Little Washington the knolls are especially prominent.

Another large area is in Ashland County west of the valley of Jerome Fork from Ashland southeast for about 14 miles to the Mohicanville Dam. The tract ranges from a mile wide in the north to 6 miles wide in the south; in the southern part rock hills and ridges with ground moraine on the surface are present within the tract. From the Mohicanville Dam northwest for 3 miles, kames form an important part of the tract, and buried kames are known to be present.

In Holmes County a very irregular tract of hummocky topography extends about 7 miles southward from the Holmes-Wayne County line near Big Prairie. Areas of ground moraine at higher elevations are within the tract.

In Wayne County, hummocky tracts are related to valley sides except in the southeastern part of the county. Here an extensive tract extends from northeast of Apple Creek village southward for 7 miles to the Wayne-Holmes County line. This tract is about 10 miles wide at the widest part. The prominence of knolls differs from place to place, and the flatter areas within the tract are mapped as ground moraine.

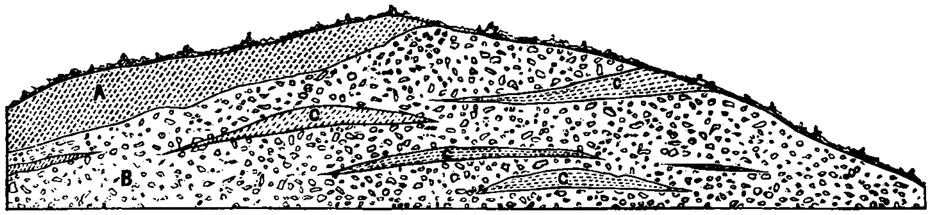
KAMES AND KAME TERRACES

Kames are circular or elongate knolls or hills of stratified material, generally gravel. In some cases the gravel may be very sandy; in most cases the gravel is coarse and may contain cobbles or even boulders. The bedding is generally at an angle. The internal structure was excellently depicted a hundred years ago by Newberry (1874, p. 44), and is reproduced in this report as figure 7. The kames were formed by meltwater which deposited more or less washed material at irregular places in and along the melting ice. At places the material is very well washed and stratified; at others it is more poorly washed, with inclusions of till masses that fell from the ice but were covered before they were completely washed. Kame gravels thus tend to be variable and range from fine to coarse grained and even to cobbly and bouldery.

Kame terraces are stratified deposits along valley sides. Some terraces are made up of closely packed kames, but others are more level, with kames rising above the general level in places. The kame terraces were formed along ice masses remaining in valleys after the ice had melted from the hills and ridges. Water flowed between the elongated ice masses and the valley walls. Where the current was swift, only coarse material was deposited, but where the current was slower, fine material was deposited. At places the water was ponded in the valley and formed temporary lakes in which sand and even silt could settle. Some ice blocks were buried in the growing deposit and, upon melting, depressions—kettle holes—were formed. Kettle holes that are still at or below the water table are now the sites of lakes, ponds, or swamps. Upon final melting of the ice masses in the center of the valley, the elongated depressions formed large kettle holes. The Portage Lakes in Summit County are excellent examples of such large kettle lakes.

Most kames in northeast Ohio, except those in central Summit County, have a covering of till of later age. This is

PROFILE SECTION OF BUCK HILL, STARK COUNTY, OHIO.



A. sand. B, gravel, sand, and bowlders. C, sheets of sand.

FIGURE 7.–Sketch of a section of Buck Hill, a kame in western Canton, Stark County (from Newberry, 1874, p. 44). It is probably the earliest such diagram in the United States. Newberry described the kame as being 40 feet high with a base 560 feet above Lake Erie.

especially the case in north-central Summit County, where distinctive clayey and silty till overlies the kames to such thickness that the area is mapped as the Summit County morainic complex and is shown as hummocky till rather than as kames (fig. 6). At places, however, the kames are exposed at the surface. In northeastern Summit, northwestern Portage, and south-central Geauga Counties the Kent Moraine is composed of kames buried by later till. This part of the moraine contrasts sharply with the eastern part of the moraine, where the kames form the surface in most places. The material exposed at the surface and hence the soil types are quite different. The topography, however, is very hummocky in both parts of the moraine.

The kames and kame terraces are very apparent on plate 1. The greatest expanse of kames and kame terraces in Ohio is the kame-moraine portion of the Kent Moraine extending from central Geauga County across northwestern and western Portage County, central and southeastern Summit County, and much of Stark County as far south as Canton. The topography is one of sharp knolls and kettle holes.

The Buck Hill Moraine, which joins the Kent Moraine in northern Canton, is mainly composed of kames and is therefore a kame moraine. From Buck Hill in western Canton northward into Summit County, large tracts of the moraine are composed of sharp, high kames. The area north-northwest of Canton and extending into Summit County has many tens of square miles of very conspicuous knoll and kettle topography. Very sharp kames, some as much as 100 feet high, are in a tract of several square miles east of the Nimisila Reservoir in extreme southern Summit County. This area is so striking it would be a good candidate for a county or state park. Most of this great area of combined Kent and Buck Hill Moraines is an excellent example of a kame moraine. The best displayed kame terraces, which are a part of the moraine, are along the Cuyahoga River valley in Geauga and northern Portage Counties.

Very well developed kame terraces are present along valley sides in the Kent Moraine in the glaciated northern portion of Columbiana County and in southern Mahoning County. At places between the valleys in Columbiana County, buried kames are extensive, particularly west of Guilford Lake and extending northward to Salem. The tops of some of the buried kames are exposed at the surface, but only a few of these can be shown on plate 1.

Imposing kame terraces extend for 12 miles along both sides of the Pymatuning Creek valley in northeastern Trumbull and southeastern Ashtabula Counties. This valley lies within the Defiance Moraine and cuts diagonally through it at a very low angle.

In the Killbuck lobe very prominent kame terraces more than 100 feet high are present along the Tuscarawas River valley from the common corner of Wayne, Summit, and Stark Counties southeast and south past Massillon almost to the glacial boundary. The northern parts of these terraces may be regarded as the western part of the Buck Hill Moraine. Prominent kame terraces are present in many valleys in Holmes County, especially along the Killbuck Creek and Martins Creek valleys.

One of the most continuous kame terraces extends for 28 miles along both sides of the valley of Jerome Fork from its head at Nankin, Ashland County, southeast to its junction with Lake Fork, along the latter valley into Holmes County, and thence to the glacial boundary. The terraces in the Lake Fork valley are especially noteworthy, being as much as 100 feet above the valley floor in places.

In Richland and Ashland Counties the kame terrace in the Black Fork valley extends from northern Richland County near Rome southeast past Mifflin in Ashland County and thence to Loudonville. The most impressive kame terraces in northeastern Ohio are those on the south side of the valley of Black Fork from Perrysville to Loudonville. The view northward from the road that ascends the slope of the valley for ⅓ mile west of Black Fork at Loudonville is spectacular. At least three terraces rise one above the other for more than 200 feet and extend northwest to beyond Perrysville. The separate kames of the upper terraces rise above the general terrace levels. The terraces actually continue farther and higher up the valley wall, but the gravel is concealed by a thick till cover.

VALLEY TRAINS

After the disappearance of the ice from the valleys, or after it had melted almost entirely, meltwater deposition changed from irregular, generally coarse gravel deposits at higher elevations to more level deposits of fine gravel, sand, and silt in the lowermost parts of the valleys. These lower-level deposits are called valley trains and are included with outwash on plate 1. In many places valley trains originally extended across the valleys, but present-day streams have excavated narrow inner valleys, which may be wide enough to contain floodplains below the original valley trains, which are preserved as matching terraces (outwash terraces) on either side of the valley. At places ice blocks remained and did not melt until deposition had ended; kettle holes are the record of the last ice blocks to disappear. Some of these depressions are very large and are sites of marshes. Some present-day streams flow from one kettle hole to another.

At places within some valleys the current was so sluggish that lakes rather than streams were formed. In these lakes fine-grained sand and silt were deposited, in places interbedded with coarser meltwater-stream deposits.

Unlike kame terraces, which can only be formed within the glacial boundary, valley trains continue downstream far beyond the glacial boundary. In east-central Ohio most streams drain south to the Tuscarawas River and thence by way of the Muskingum River to the Ohio River; streams in the easternmost part of the state drain to the Ohio River directly, or by way of the Mahoning River to the Ohio.

Beyond the glacial boundary, valley trains are preserved as terraces at different levels because they were formed at different times. The oldest ones are the highest. Later erosion has dissected the valley trains, the oldest and highest most severely. A full-scale investigation of these terraces is warranted to determine their extent and age. The different levels can be traced to the glacial boundary, where they can be related to different ice advances. The terraces and their material have both scientific and economic value.

In this report only some of the larger and more important valley trains will be described, especially those which extend beyond the glacial boundary. This relation is important for the eventual correlation of outwash terraces and the determination of their ages.

The valley trains in the Killbuck lobe generally filled the linear depressions below the kame terraces in the valleys. Kettle holes are generally absent in these valley trains. The valley train in the Clear Fork valley extends from the headwaters of Clear Fork to within 4 miles of the junction with Black Fork to form the Mohican River. The last 4 miles is a gorge, which is too narrow to have had a valley train. Indeed, the valley is so narrow that only the narrowest scraps of floodplain have been formed.

An interesting valley train is that in the Black Fork valley; this valley train heads in kettle holes in the lowest kame terrace at Perrysville, southwestern Ashland County. Below Perrysville, ice masses no longer remained, and the sand and gravel filled the valley bottom to form a valley train.

The junction of Clear Fork with Black Fork to form the Mohican River is at the glacial boundary; the joined valley trains descend the Mohican River valley across eastern Knox County (Root, Rodriguez, and Forsyth, 1961, pl. 5), and continue across Coshocton County in the Walhonding River valley to Coshocton and down the Muskingum River valley to Marietta, where they join the valley train of the Ohio River and continue down that valley to the Mississippi River.

In southern Medina County and northern Wayne County a very wide valley train in the upper Chippewa Creek valley has the character of an outwash plain. It extends southeastward from north of Seville past Sterling to Rittman; it is 6 miles long and 4 miles wide. Unlike the valley trains already described, this valley train has many kettle holes, especially near Sterling. From Sterling to the junction of Chippewa Creek with the Tuscarawas River in Summit County, the valley of Chippewa Creek is filled with more than 200 feet of outwash, but it is just at water level and hence no valley train appears at the surface, and the material is mapped as alluvium.

Large expanses of valley-train sand, gravel, and silt are present in low areas in central and western Summit County south and southwest of Akron. An area near Copley is 4 miles wide from west to east. This area has many large kettle holes; the largest of these is the site of Copley Marsh, which has thick peat deposits.

An extensive outwash deposit extends from Fairlawn in northwest Akron southwestward for 6 miles to Barberton. The southern part has kettle holes, the largest of which is a 3-mile-long depression between the Fairlawn outwash and the Copley area; Black Pond and White Pond occupy the deeper parts of this depression, but most of it is a peat marsh, now mostly drained. From Barberton the outwash continues south along the Tuscarawas River valley to south of Clinton. From south of Clinton to Massillon there are only small remnants of valley-train terraces. From Massillon south a great valley train, in places 2 miles wide, extends down the Tuscarawas River valley to the glacial boundary and then to the gorge near Dover, Tuscarawas County. Beyond the Dover gorge the valley train reappears and continues to the junction of the Tuscarawas and the Walhonding Rivers at Coshocton as a conspicuous series of terraces at several levels.

In northern Summit County a depression extends 10 miles south-southeast from Macedonia. Outwash silt and sand partly fill the depression. Bogs and small lakes are present in the deeper parts.

The valleys of Pond Brook and Tinkers Creek in northeastern Summit County join on the south near the Summit-Portage County line to form a distinctive Y-shaped area of outwash. The western valley, Tinkers Creek, is about 5 miles long and the eastern valley, Pond Brook, is 6 miles long. The bottoms of these valleys contain mainly very silty material, not far above water level.

In northeastern Portage and southwestern Trumbull Counties a large irregular outwash tract fills the lower parts of the valleys of Tinker Creek (not the Summit County Tinkers Creek) and Eagle Creek and part of the Mahoning River valley from north of Kirwan Reservoir past Newton Falls to Leavittsburg. The tract is more than 10 miles wide. Till-covered bedrock hills rise above the flat outwash like islands. The deposit is a mixture of sluggish-meltwater sand and lacustrine fine sand and silt. Small sand dunes are present at a few places. This area is low and poorly drained in large parts.

An extensive sandy and silty plain about 2 miles wide extends from Alliance, Stark County, southeast for 7 miles, almost to Placenta Lake, Columbiana County, where the outwash passes into kame gravel. The depression was formerly a very shallow lake in which silt was deposited. The Mahoning River meanders through this level area. The Mahoning River now flows in a general northwesterly direction from its headwaters in western Columbiana County to Alliance, Stark County, and thence in a general northeasterly and northerly direction for 20 miles to Newton Falls, Trumbull County. In glacial times the drainage was south through a spectacular deep, narrow gorge at Chambersburg, Columbiana County. After the disappearance of the ice to the north, northward drainage was resumed, and the gorge was abandoned. The outwash in the valley from Alliance to the headwaters was deposited by southward-flowing meltwater. Kame terraces were formed to the south, but valley-train material and some lacustrine silt were deposited in the wide valley southeast of Alliance.

A prominent generally poorly drained valley train in the valley of Mill Creek extends from Boardman, Mahoning County, southward to 3 miles southwest of Columbiana, Columbiana County. The valley train is composed of sand and silt deposited in sluggish streams and shallow lakes.

In western Columbiana County and southeastern Stark County, valley trains in the valleys of Conser Run, upper Sandy Creek, and Hugle Run begin north of the glacial boundary, pass into the unglaciated area, join, and pass southwest to join the valley train in the Nimishillen Creek valley. These impressive flat deposits of gravel are as much as 2 miles wide.

Most of the city of Canton is built on a great valley train, so wide it is really an outwash plain. It is 3 miles wide and passes south in the Nimishillen Creek valley as a very narrow valley train to join the much wider Sandy Creek valley train in northern Tuscarawas County. The combined valley trains thence continue in the Sandy Creek valley to the Tuscarawas River.

A very wide valley train in the Sugar Creek valley extends from the glacial boundary at Beach City, southwestern Stark County, southward past Strasburg, Tuscarawas County, to Dover, where it joins the valley train of the Tuscarawas River. This flat outwash area is 3 miles wide at the glacial boundary, but decreases to 2 miles at Strasburg. The sand and gravel of this deposit is reported to be more than 200 feet thick in places.

Outwash in the Mahoning River valley in eastern Trumbull and Mahoning Counties extends from Mosquito Creek Reservoir to Niles. Very thin outwash in the Mosquito Creek valley extends from the Mosquito Creek Reservoir dam southward to join the valley train in the Mahoning River valley at Niles. The material in the Mosquito Creek valley is very fine grained; the deposits in the center of the valley, essentially at the water level of the stream, are mainly lacustrine in origin. The valley train in the Mahoning River valley from Niles past Youngstown to the Ohio-Pennsylvania state line is preserved as terraces, narrow and discontinuous as far as Girard, but more continuous from Girard southeast. Much of Youngstown and the steel mills above and below the city are built on this outwash.

In northeastern Columbiana County, valley trains are present in the valleys of West Fork, Middle Fork, and North Fork Little Beaver Creek. The valley train in the West Fork valley is just south of the glacial boundary and parallels it

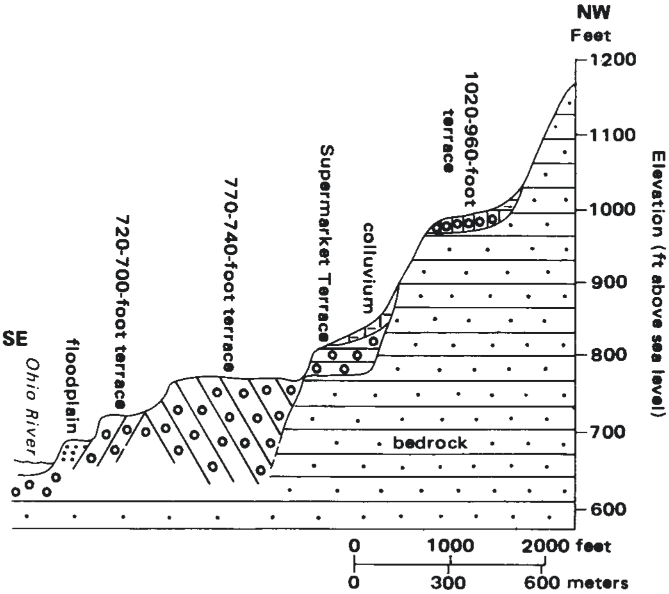


FIGURE 8.—Profile of terraces on the north side of the Ohio River valley at East Liverpool, Columbiana County (modified from Lessig, 1959, p. 337). The 720-700-foot terrace is Kent (Woodfordian) in age; the 770-740-foot terrace is Titusville (Altonian) in age; the Supermarket Terrace is probably Illinoian in age; the 1020-960-foot terrace is pre-Illinoian in age (age assignments made by George W. White).

for 13 miles to the junction with Middle Fork. Along the Middle Fork valley from Lisbon southeast for 13 miles to the junction with North Fork, valley trains of several ages are present. The higher, older deposits remain only as isolated terrace remnants. In North Fork, prominent valley trains at two levels are present at Negley, but south of Negley to the junction with Middle Fork and on to the Ohio River, a distance of 10 miles, the outwash is very discontinuous.

Although the outwash in the Little Beaver Creek drainage system does not cover a very large area, it is important because it enables correlation with deposits in the Ohio River valley. From the Ohio-Pennsylvania-West Virginia state line past East Liverpool and Wellsville, Columbiana County, and thence downstream past Cincinnati, outwash terraces at as many as four levels (fig. 8) record the deposition of valley trains during several glacial episodes, ranging in age from at least Middle Pleistocene to latest Pleistocene. These various levels of outwash have been delineated in the very detailed investigations and papers by H. D. Lessig (1961) and Lessig and others (1968). The determination of the ages of the till sheets and associated outwash in the glaciated region makes possible the age determination of the Ohio River valley terraces with some degree of assurance for the lower ones and some degree of probability for the higher ones.

Chapter 4

TILLS AND RELATED DEPOSITS

The greatest bulk of the glacial deposits in northeastern Ohio is of the Wisconsinan Stage, the latest stage in glacial history (see table 1). However, at places below the Wisconsinan tills, deposits of earlier much-weathered generally very coarse till of pre-Wisconsinan age are found. Deposits of the several glacial advances are sufficiently distinctive to be separated in exposures. It is expected that in any very large exposure of considerable thickness the glacial material will have been deposited by more than one ice advance and will differ more or less in character. In many laterally extensive exposures it may be seen that one or more of the tills is variable in thickness and may not be everywhere present. This is especially true of the pre-Wisconsinan tills, which have suffered much erosion so that only fragments are preserved in low places (figs. 9, 10). It is also true of the late Wisconsinan tills, which may be thin and discontinuous. Indeed, the early Wisconsinan till is the most continuous and thickest till throughout northeastern Ohio.

CLASSIFICATION

Four major glacial stages of the Pleistocene Epoch, separated by warmer interglacial intervals, are generally recognized in the central United States. These divisions, their representation in northeastern Ohio, and the post-glacial episode are shown in table 1.

The tills of the Wisconsinan, Illinoian, and tentatively of the Kansan Stages and their correlation in the different lobes are shown in table 2. The boundaries of the tills exposed at the surface are shown on plate 1 and in figure 5.

CHARACTER AND COMPOSITION OF THE TILL

The various tills in northeastern Ohio differ among themselves in texture, mineral and lithologic composition, color, and weathering character. These properties are discussed for each till in the area of the Allegheny Plateau in general. In northeastern Ohio, tills of six ice advances form the surface drift, but tills of only three of these advances account for most of the surface material. At some places where a later till is thin or missing, an earlier till may be exposed at the surface in small areas. Earlier tills are exposed in a few ravines and excavations. The thickest drift is present in the deep bedrock valleys. The till of the uplands is thin in most places. The stratigraphy and characteristics of the tills are varied and complicated because they were deposited at different times and in three different lobes.

TEXTURE

Tills in northeastern Ohio range from sandy tills with a low clay content to clayey tills with a low sand content. The texture of each till is reasonably constant over a large area. The tills at the surface in northeastern Ohio north of the Hiram Till margin (fig. 5) are clayey or silty with few cobbles and rare boulders. Some sandy till is found below these fine-grained tills. The area north of the Hiram Till margin is characterized by the very distinctive heavy Mahoning-Ellsworth soils or their close relatives. The tills south of the Hiram Till margin are generally coarse and sandy, with cobbles and boulders. Wooster-Canfield-Ravenna silt loams and silty sandy loams generally are developed on these tills. A summary of the textures of the various tills in the Grand River lobe in Ohio and Pennsylvania is shown in table 3. It must be remembered that these averages are for a large area, that the tills differ from place to place, and that they change in an orderly manner in a southerly direction, becoming less clayey to the south, as discussed later. A summary of the textures in the Grand River lobe in Ohio is shown in table 4, and a summary of textures in the Killbuck lobe is shown in table 5.

When studied over a whole lobe, the texture of all the tills appears to change at a slowly decreasing rate from north to south and toward the margins of the lobe. For the eastern part of the Grand River lobe in Pennsylvania the rate of change of sand, silt, and clay has been shown by vector analysis by White, Totten, and Gross (1969, fig. 9). The clay in the Kent Till decreases toward the margin at 0.17 percent per mile; in the Titusville Till the clay decreases 0.08 percent per mile. The sand in the Titusville Till increases 0.33 percent per mile. A second-order vector trend-surface analysis confirms the increases in sand (White, Totten, and Gross, 1969, fig. 10), and further shows that the rate of increase declines and the sand content remains constant in the outer 20 miles of the lobe, indicating that erosion had ceased and that the glacial action was essentially one of deposition. The changes in the Grand River lobe in adjacent Ohio are similar to those in Pennsylvania.

MINERAL COMPOSITION

Tills differ in content of quartz, feldspar, carbonate minerals, and some other minerals, but each till has a characteristic mineral content (table 3). Quartz content ranges from 68 to 94 percent, being highest in the older tills. The earlier tills incorporate a higher proportion of sandstone fragments, whereas the later tills have a higher proportion of feldspar and carbonate minerals derived from crystalline rock fragments from the Canadian Shield and limestone fragments from the bottom of Lake Erie. The mineral proportions in all the tills show a gradual increase in quartz and a gradual decrease in feldspar toward the lobe boundaries. In the Grand River lobe in adjacent Pennsylvania this

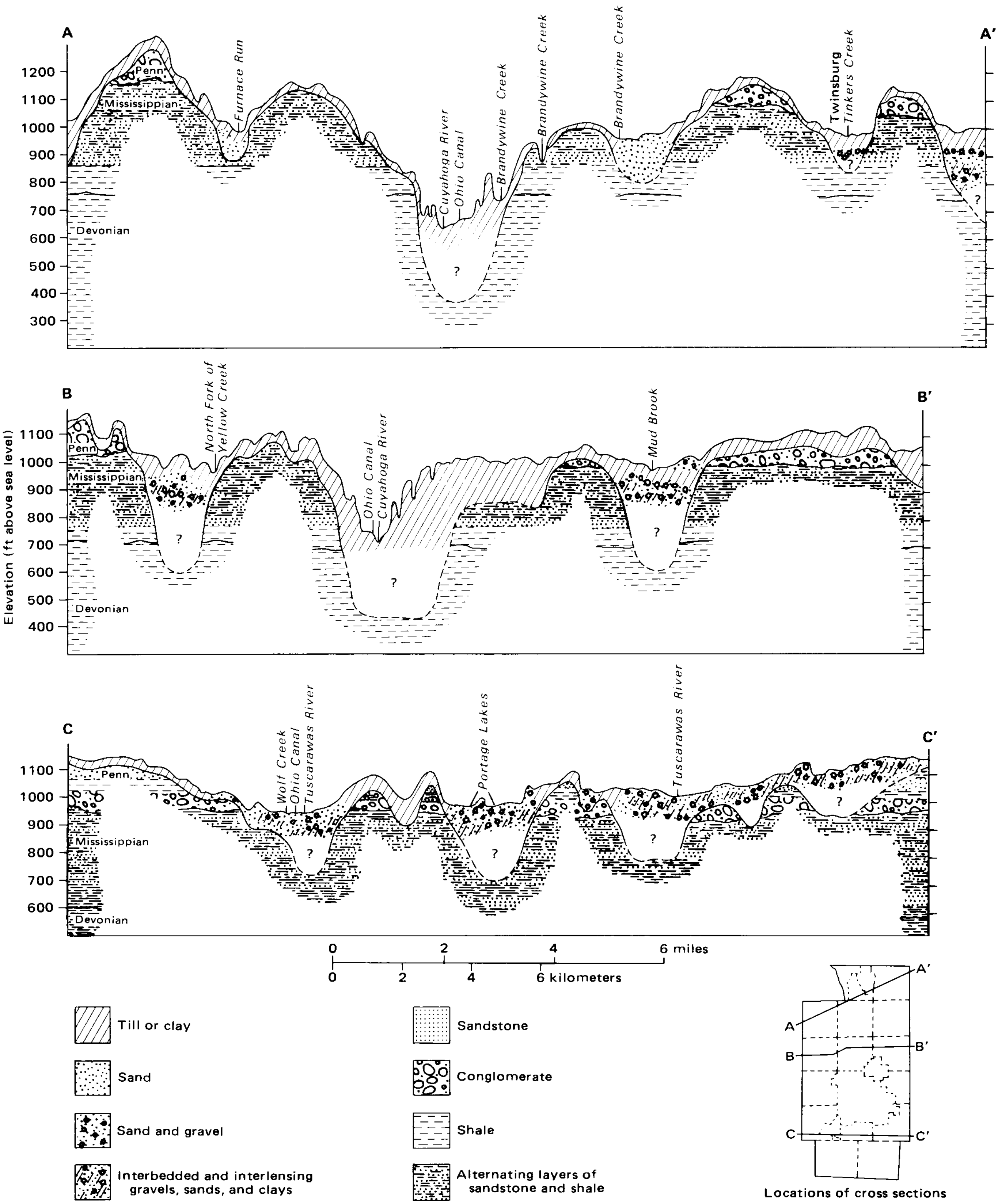
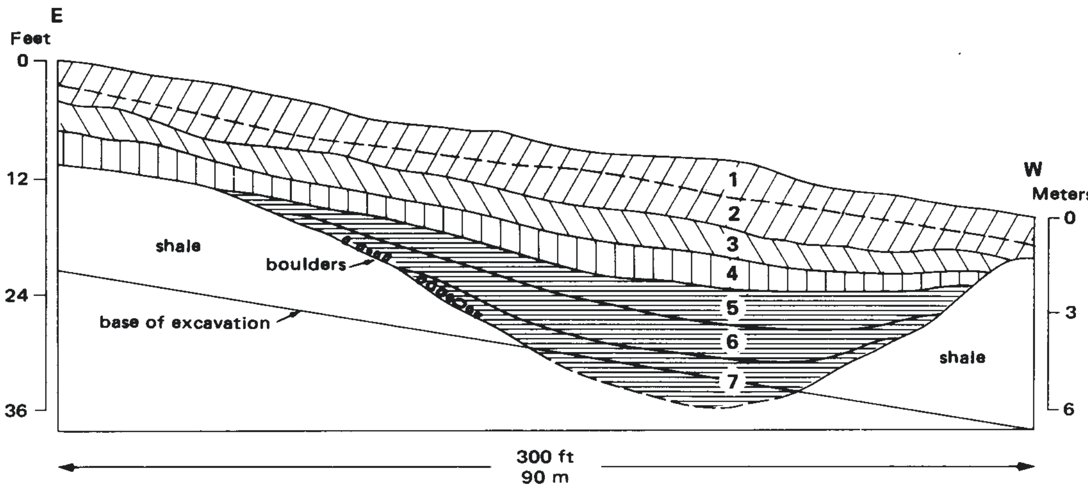


FIGURE 9.–Generalized cross sections across Summit County showing bedrock geology, deep preglacial and interglacial valleys, and drift cover (modified from Smith and White, 1953, pl. 7).



1. Till, chocolate-brown, noncalcareous. HIRAM
2. Till, chocolate-brown, calcareous; 20% sand, 24% clay. HIRAM
3. Till, brown, calcareous; 34% sand, 17% clay. LAVERY
4. Till, olive-brown, calcareous; 36% sand, 18% clay. TITUSVILLE
5. Till, gray, noncalcareous; 29% sand, 20% clay. MAPLEDALE
6. Till, bright-gray, noncalcareous; 48% sand, 13% clay. MAPLEDALE
7. Till, gray, calcareous. MAPLEDALE

FIGURE 10.—Sketch of tills in cut for I-80, 1½ miles southwest of the center of Girard, Trumbull County, showing older till preserved in small buried valley (modified from White, 1971b, fig. 3).

TABLE 1.—*Glacial stages of the Pleistocene Epoch*

Epoch	Glacial and interglacial stages	Deposit in northeastern Ohio
Holocene (Recent)		Stream deposits (alluvium); swamp deposits (peat, muck); beaches and other deposits on Lake Plain
Pleistocene	Wisconsinan	Most drift of northeastern Ohio; several divisions, see table 2
	Sangamonian	Period of weathering and erosion; rare buried soils (paleosols)
	Illinoian	Eroded till in widely separated areas
	Yarmouthian	Long period of weathering and erosion; some very rare paleosols
	Kansan	Slippery Rock Till of Pennsylvania; pre-Illinoian till in widely separated areas in Ohio may be correlative
	Aftonian	Period of weathering and erosion
	Nebraskan	None definitely known in Ohio (see text)

TABLE 2.–*Correlation of tills in northeastern Ohio*

WISCONSINAN	WOODFORDIAN	*Erie lobe:* Ashtabula Till			
		Scioto lobe	*Killbuck lobe*	*Cuyahoga lobe*	*Grand River lobe*
		Centerburg Till Mt. Liberty Till Knox Lake Till	Hiram Till Hayesville Till Navarre Till	Hiram Till Lavery Till (concealed)	Hiram Till Lavery Till Kent Till
	FARMDALIAN	Paleosol			
	ALTONIAN	Jelloway Till	Millbrook Till	Mogadore Till	Titusville Till
SANGAMONIAN		Paleosol			
ILLINOIAN		Butler Till	unnamed till	unnamed till	Mapledale Till (subsurface only)
KANSAN			unnamed till	unnamed till	Slippery Rock Till? (subsurface only)

TABLE 3.–*Mean grain size and feldspar content of the tills*[1]

Till	% Sand			% Silt			% Clay			% Total feldspar			% Potassium feldspar		
	X[2]	S	N	X	S	N	X	S	N	X	S	N	X	S	N
Ashtabula	28	7.8	65	46	5.0	65	26	7.0	65	32	7.7	37	39	12.2	37
Hiram	$\overline{20}$	9.5	180	45	6.6	180	$\overline{35}$	11.3	180	$\overline{27}$	6.8	158	$\overline{44}$	10.2	158
Lavery	$\overline{30}$	9.2	85	45	5.7	85	$\overline{25}$	6.9	85	$\overline{21}$	9.3	51	45	13.8	51
Kent	$\overline{41}$	8.3	304	$\overline{41}$	7.0	304	$\overline{18}$	5.8	304	$\overline{17}$	6.8	141	$\overline{49}$	12.9	141
Titusville	$\overline{45}$	7.1	389	$\overline{37}$	6.0	389	18	4.5	389	$\overline{13}$	7.0	326	50	17.6	326
Mapledale	$\overline{42}$	7.8	44	36	5.5	44	$\overline{22}$	5.7	44	$\overline{6}$	3.6	32	55	19.0	32

[1] Modified from Gross and Moran, 1971, p. 254.
[2] X = mean; S = standard deviation; N = number of samples; $\overline{\ \ }$ = significantly different at a 95 percent level of confidence.

TABLE 4.–*Average composition of tills of the Grand River lobe*

County	Hiram Till			Lavery Till			Kent Till			Titusville Till			Mapledale Till		
	% sand	% silt	% clay	% sand	% silt	% clay	% sand	% silt	% clay	% sand	% silt	% clay	% sand	% silt	% clay
Columbiana				26	45	29	43	30	27	49	32	19	39	36	25
Mahoning	10	48	42	33	41	26	45	38	17	43	38	19			
Portage	12	41	48	24	45	31	32	47	24	44	38	18			
Stark				28	40	33	46	36	19						
Trumbull	20	47	33	27	48	25	36	45	19	43	40	17			

TABLE 5.–*Average composition of tills of the Killbuck lobe*

County	Hiram Till			Hayesville Till			Navarre Till			Millbrook Till		
	% sand	% silt	% clay	% sand	% silt	% clay	% sand	% silt	% clay	% sand	% silt	% clay
Ashland	21	43	36	28	43	29	33	46	21	36	45	19
Holmes				31	45	25	45	37	18	41	42	17
Richland	23	47	30	25	48	27	36	44	20	41	42	17
Stark				31	45	24	47	37	16			
Wayne	26	46	28	26	46	29	41	42	17	44	42	15

change is shown by vector analysis by White, Totten, and Gross (1969, fig. 9); the feldspar content of the Kent Till decreases 0.38 percent per mile and that of the Titusville Till 0.41 percent per mile. In the Grand River lobe in both Ohio and Pennsylvania the decrease in feldspar content toward the lobe margin in Titusville, Kent, and Lavery Tills is shown by isopleths by Gross and Moran (1971, figs. 2-13); their figure for the Kent Till is reproduced here as figure 11. This till shows, as do the other tills, the delicate control of mineral content by ice-flow direction, which is controlled by topography. Currents within the ice sheet moved down lowlands and deep valleys, carrying drift of the same composition much farther than on the uplands.

The carbonate content, composed of both calcite and

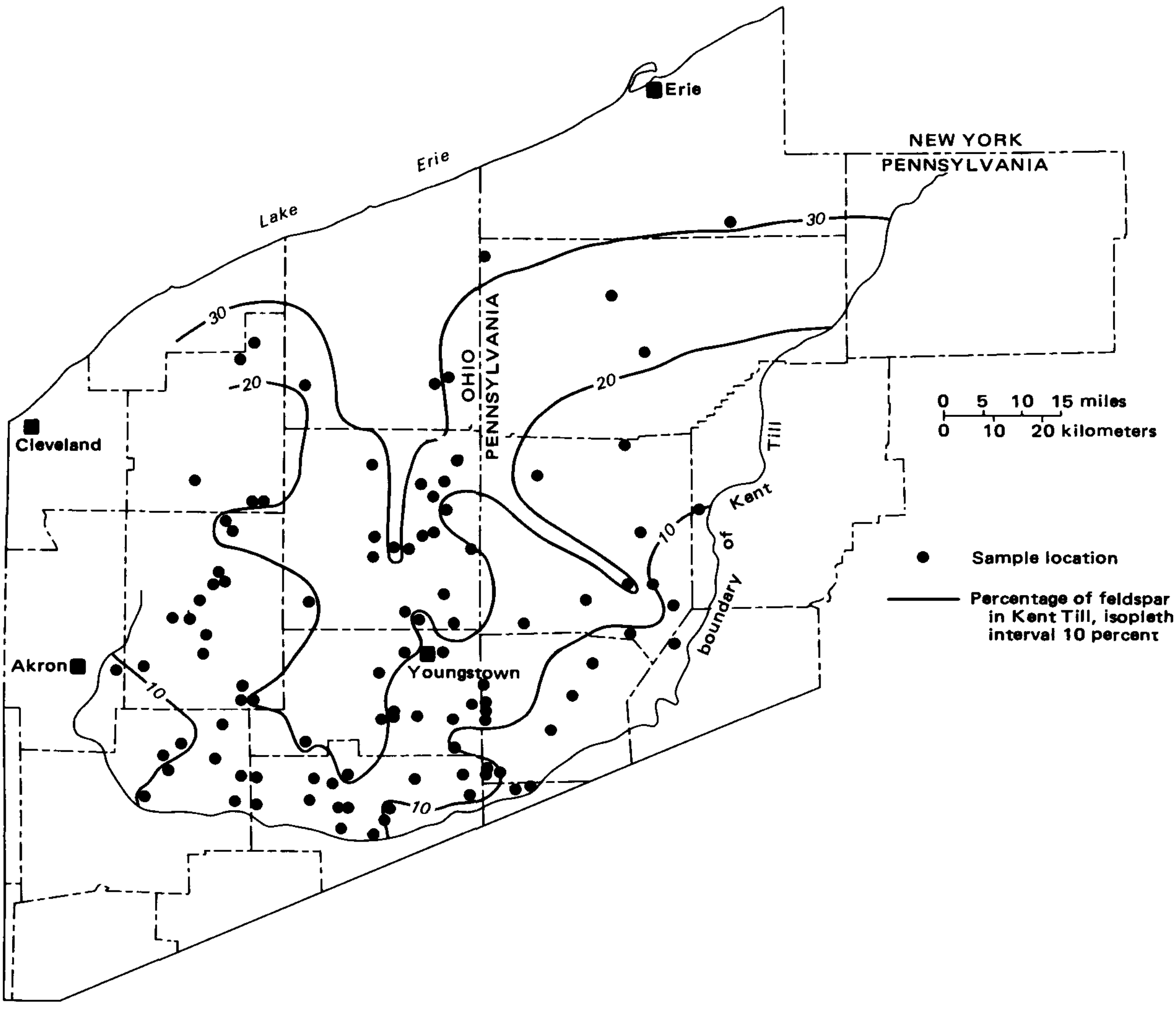


FIGURE 11.–Percentage of feldspar in Kent Till of Grand River lobe in Ohio and Pennsylvania (modified from Gross and Moran, 1971, p. 258, fig. 3). Computer-drawn isopleths show a decrease in feldspar toward the drift margin.

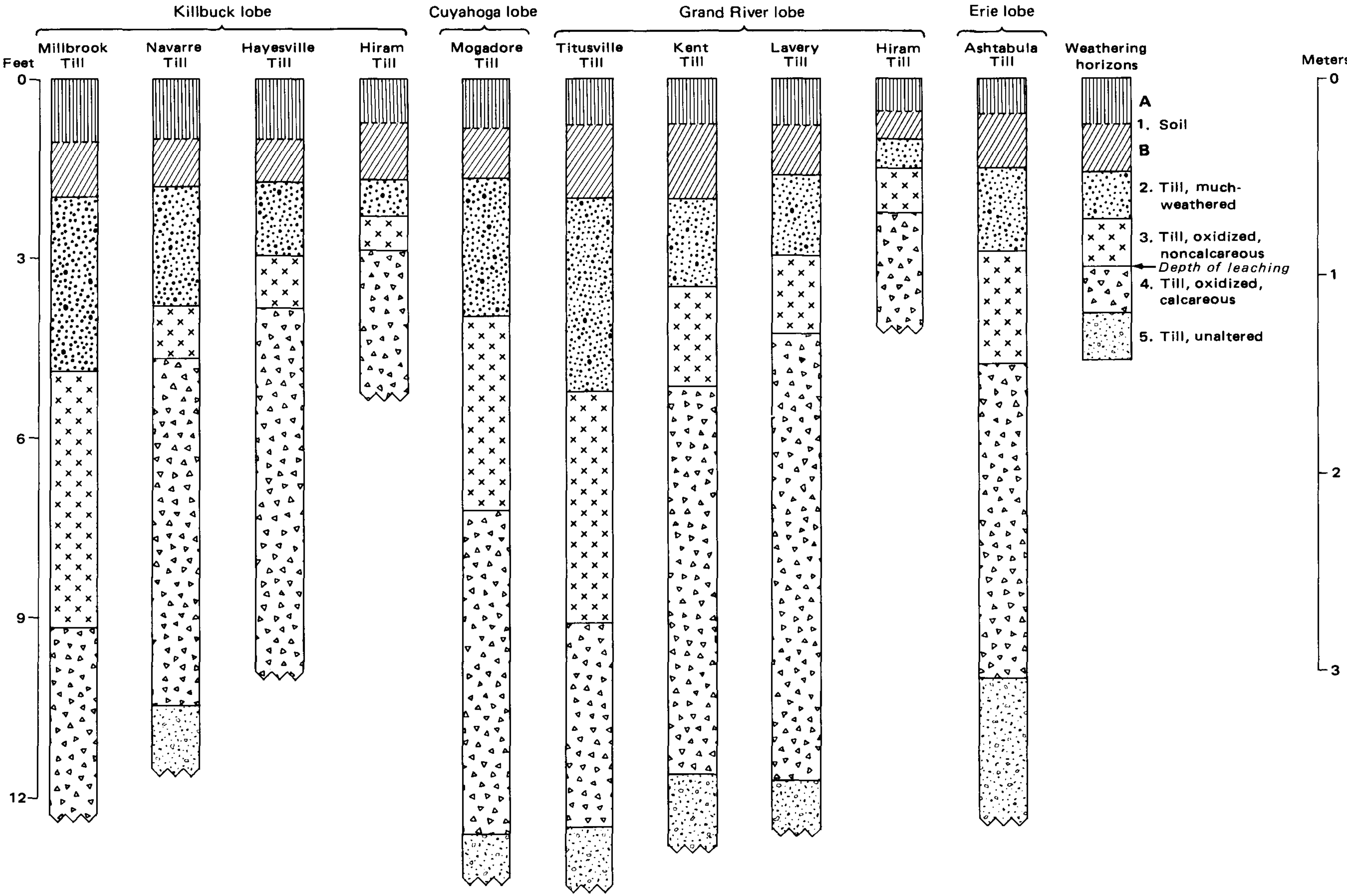


FIGURE 12.—Average weathering horizons of tills in northeastern Ohio. Age of till decreases from left to right for Killbuck and Grand River lobes.

dolomite, of unaltered till ranges from less than 1 percent to more than 15 percent. The carbonate content is lower in the older tills and higher in the younger tills. The older tills contain more fragments of local siliceous rock, whereas the younger tills have a higher proportion of fragments of limestone and dolomite from the basin of Lake Erie.

Clay mineralogy has been investigated for tills in some areas, but not over as wide an area as quartz and feldspar. The predominant clay mineral in unaltered till is illite, with smaller amounts of chlorite and kaolinite. Droste (1956a, p. 189) found the mean values of samples he analyzed to be: illite, 60 percent; chlorite, 35 percent; and kaolinite, 5 percent.

COLOR

Unaltered tills are various shades of gray. Exposures of unaltered (unoxidized) till may be seen along steep valley walls and in deep excavations. Oxidized tills are brown, ranging from dark brown to dark yellow brown to yellowish brown to olive brown. The younger oxidized tills are generally dark brown, tending toward chocolate brown. The older oxidized tills are yellow brown or olive brown. The cause of the differences in color of the oxidized till is not completely understood. Unpublished studies of the late R. F. Sitler (personal commun., *c.* 1965) indicated that the younger tills, higher in carbonates, have a darker brown color. Sitler's work indicated that the kind of iron sulfide (pyrite or marcasite), whether derived from broken crystals in crystalline rocks, from Devonian black shale, or from framboids (a form of secondary pyrite in sedimentary rocks), differs in various tills, but his work had not reached the stage of quantification before his untimely death.

WEATHERING CHARACTER

Where the upper part of a till has not been removed by erosion or the work of man, the till can be divided vertically into five distinct horizons, based on degree of weathering, as shown in figure 12. In the weathering of till the first minerals to be attacked are the iron-bearing minerals, especially pyrite. These minerals are oxidized, furnishing the brown color to the weathered till. Carbonates are leached, and the most resistant minerals, the silicates, are degraded.

Horizon 5 is the unaltered till; the iron-bearing minerals have not been oxidized, and the carbonates have not been leached. This horizon is sometimes called "blue clay with stones," but the color is actually some shade of gray rather than blue. The top of horizon 5 is 8 to 18 feet below the surface.

Horizon 4 is calcareous till similar to that of horizon 5, except it is oxidized to a brown color. This oxidized color is distinctive for each till; the color ranges from dark brown through yellow brown to olive brown. The top of horizon 4 is also the depth of leaching, which ranges from less than 2½ feet below the surface in the Hiram Till to 8 feet or more in older tills.

Horizon 3 is similar to horizon 4, except that in horizon 3 the carbonates have been leached. Iron oxide and manganese stains may be present along joints and around pebbles. These stains are generally more pronounced in the older tills.

Horizon 2 (essentially the B3 horizon of soil scientists) is the zone of decomposed till underlying the main part of the true soil. This horizon is not only oxidized and leached, but also is considerably weathered; some of the pebbles and cobbles may be decomposed. Some clay material has accumulated in the joints, and soil-forming processes are advanced. The material is not so completely weathered, however, that it cannot be identified as once having been till. The color of the upper part is generally a mixture of buff, gray, and brown. The lower part may have dark stains along the joints.

Horizon 1 is the soil, divided into the A and upper B soil horizons by soil scientists. The characteristics of the soil differ with drainage and slope, as well as with parent material. The soils are dealt with in great detail in recent reports with very detailed maps for Ashland County (Redmond and Brown, 1980), Ashtabula County (Reeder and others, 1973), Columbiana County (Lessig and others, 1968), Cuyahoga County (Musgrave and Holloran, 1980), Lake County (Ritchie and Reeder, 1979), Lorain County (Ernst and others, 1976), Mahoning County (Lessig and others, 1971), Medina County (Hayhurst and others, 1977), Portage County (Ritchie and others, 1978), Richland County (Redmond and others, 1975), Stark County (Christman and others, 1971), and Summit County (Ritchie and Steiger, 1974).

The clays in the till are changed progressively as weathering increases upward; the degradation of clays was studied by Droste (1956b). Chlorite is eventually changed to vermiculite, illite is partly degraded, and the small amount of kaolinite is not affected. These changes are discussed in detail by Droste and Tharin (1958).

The character of the weathering of clayey tills was recognized at least 100 years ago. Early workers, and to an extent even some later workers, regarded the oxidized brown ("yellow") upper part of the till as a different deposit

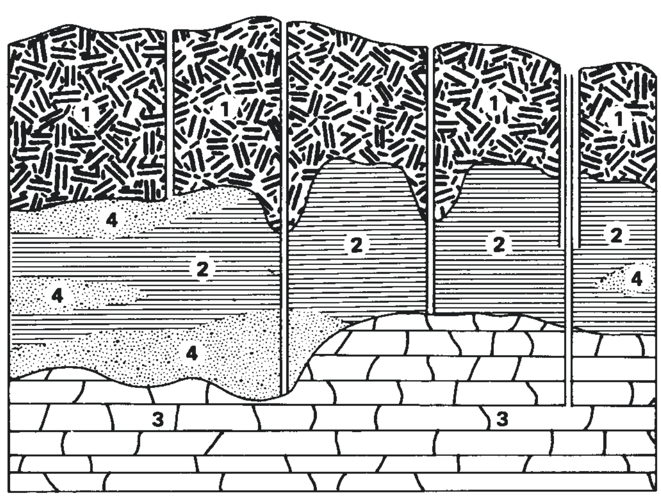


FIGURE 13.–"Succession of material" in "clay-drift" in northern Summit County (modified from Read, 1880, p. 491). Probably thin Hiram Till and underlying Lavery Till are included.

than the unoxidized gray till below. The astute lawyer-naturalist-geologist M. C. Read of Hudson recognized (1880) that the upper part of clay till was weathered to a yellow color and below an irregular boundary was the unaltered gray till. He also noted the characteristic "joints" in the clay tills of northern Summit County which divide the lower part of the soil into small blocks. Figure 13 copies Read's diagrammatic sketch of northern Summit County drifts, perhaps at a locality north of Hudson where the bedrock is close to the surface.

STRUCTURE

Internal structural features differ from till to till. Density may be markedly different. The earlier tills—Altonian and pre-Altonian—are much more dense than later tills. This difference is discernible when driving tubes for securing samples for engineering analysis; the later tills may require 10-14 blows per foot of penetration, whereas the earlier tills may require 50-70 blows per foot. The change in blows per foot of penetration is sharply evident. In surface outcrops the difference in resistance to the pick, the common tool of the glacial geologist, is immediately evident.

The structure of weathered tills also differs from till to till, and the variety of fracture patterns is significant. The spacing and attitudes of jointing are diverse. In the Altonian tills the fractures are especially evident because of strong oxidation along them. In horizon 3 and upper horizon 4, in addition to the more or less vertical fractures, a subparallel, subhorizontal, platy structure is commonly evident. In the Woodfordian tills, more closely spaced vertical joints divide the till into small rectangular blocks, which continue to subdivide so that in the subsoil small nut-sized fragments (peds) are produced (nusiform soil structure).

The variation in structure is an important factor for movement of fluids through till. Intergranular permeability is very low, but fluids may travel through the joints. This factor must be taken into account in testing for permeability of potential septic-tank and waste-disposal sites. Also to be considered is the opening of near-surface joints in dry seasons by desiccation, a feature noted a hundred years ago by Read (1880) in the area of clayey till in northern Summit County.

THICKNESS OF TILLS

The separate till sheets in northeastern Ohio are up to 110 feet thick. The median thickness of Woodfordian tills is 5 feet, whereas the median thickness of Altonian tills is 16 feet. At more than one-fourth of the outcrops the thickness of the Altonian tills is 27 feet or more. The uppermost till in almost all places characteristically is very thin and may be so thin that it is incorporated in the modern soil. Table 6 shows the thicknesses of tills, and figure 14 presents these data in graphic form.

At places a till may thicken noticeably from the normal; such "abnormal" thickness is interpreted to be the result of thrust stacking, a phenomenon studied in detail by Moran (1971).

The realization that individual tills may be only a very few feet thick is important for engineering and environmental studies and design. Different tills have different characteristics, and the interfaces between till sheets are paths for fluid transmission. Almost any excavation more than a few feet deep will probably encounter more than one till.

Silt or sand layers are common at till interfaces. These layers range from a fraction of an inch to several feet thick. At some interfaces a layer of more or less closely spaced cobbles and boulders may occur. These boulder pavements present problems which may be severe in some excavations, particularly in tunnelling (White, 1972, 1974).

It is noteworthy that not only are Woodfordian tills thin, but they may actually be so thin that they are only in the present soil, or may even be missing completely, as indicated for the Kent and Navarre Tills in figure 14. It should be emphasized that the bulk of the till in much of northeastern Ohio is not the till at the surface, but the earlier Altonian till.

TABLE 6.—*Thickness of Wisconsinan tills*[1]

Till	No. of measurements	Range (ft)	Mean (ft)	Q_1 (ft)	Q_2 (median) (ft)	Q_3 (ft)
Grand River lobe						
Hiram	84	0- 25+	5.8	3	4	7
Lavery	37	0- 11+	5.0	3	4	6
Kent	131[2]	0- 25+	6.8	4	5	8
Titusville (total)	73	0-110+	20.2	11	16	27
Titusville I	25	3- 16	9.2	6	9	12
Sand below Titusville I	25	0- 25	3.1	0	1	2½
Killbuck lobe						
Hiram	41	0- 22	8.3	4	6	11
Hayesville	113	0- 20	5.2	4	5	6
Navarre	90[3]	0- 18	6.9	4	6	9
Millbrook	20	0- 54	12.6	5	8	15

[1] From White, 1971a, p. 151, table 1.
[2] Only 116 finite thicknesses used for quartiles (Q) and mean.
[3] Only 60 finite thicknesses used for quartiles and mean.

PRE-KANSAN? DRIFT

The evidence for very early (pre-Kansan?) glaciation is of two kinds. In Stark County, 16 miles south of Canton and as much as 8 miles south of the glacial boundary as mapped, a few rare erratic boulders and cobbles have been discovered (Bognar, 1926; Jackson and Bain, 1974). The location of these boulders is indicated on plate 1. Two or three crystalline cobbles have been noted 2 miles south of the glacial boundary in Carroll County; they are probably erratics, but are not shown on plate 1. Similar erratics far beyond the glacial boundary have been mentioned by Goldthwait (1979).

The second type of evidence of early Pleistocene glaciation is an extensive laminated silt deposit as much as several feet thick on the uplands in Columbiana County south of the glacial boundary. This deposit has been described in detail by Lessig (1963), who named it the Calcutta Silt. It is present on uplands as high as 1,180 feet in elevation. It was deposited in ponded water of northward-flowing streams dammed by an early ice advance. These streams were then flowing at a much higher level than the present drainage. Similar high-level silts exist in Washington County (Collins and Smith, 1977, p. 7) and have been noted by the present author on uplands in Noble and Monroe Counties at elevations similar to that in Columbiana County. These silts, like that in Columbiana County, require the presence of early Pleistocene ice to pond the northward-flowing drainage.

It is impossible to classify these early deposits as Nebraskan or Kansan. It is probable that the classical classification of pre-Illinoian deposits as Nebraskan and Kansan will undergo revision; study of deep-sea cores and other evidence indicate that the Pleistocene Epoch was much longer than previously supposed.

KANSAN GLACIAL STAGE

At a very few outcrops in strip mines in northwestern Pennsylvania a very early till named the Slippery Rock Till (White, Totten, and Gross, 1969, p. 11-15) is found. It is deeply weathered and is overlain by fresh Mapledale Till of Illinoian age. The Slippery Rock Till is interpreted as pre-Illinoian, possibly Kansan. Several tills in Ohio below Illinoian till may be correlative with the Slippery Rock Till (Totten, 1965).

Much-weathered till below Mapledale Till has been exposed in a deep strip mine in SE¼NE¼ Sec. 1, Center Township, Columbiana County. The best exposure in northeastern Ohio of a till that has a deep paleosol preserved below Illinoian till was discovered by H. D. Lessig in a strip mine (now abandoned) at Elkton, Columbiana County, 4 miles east of Lisbon. This till has been interpreted as Kansan in age and has been described in detail by Lessig and Rice

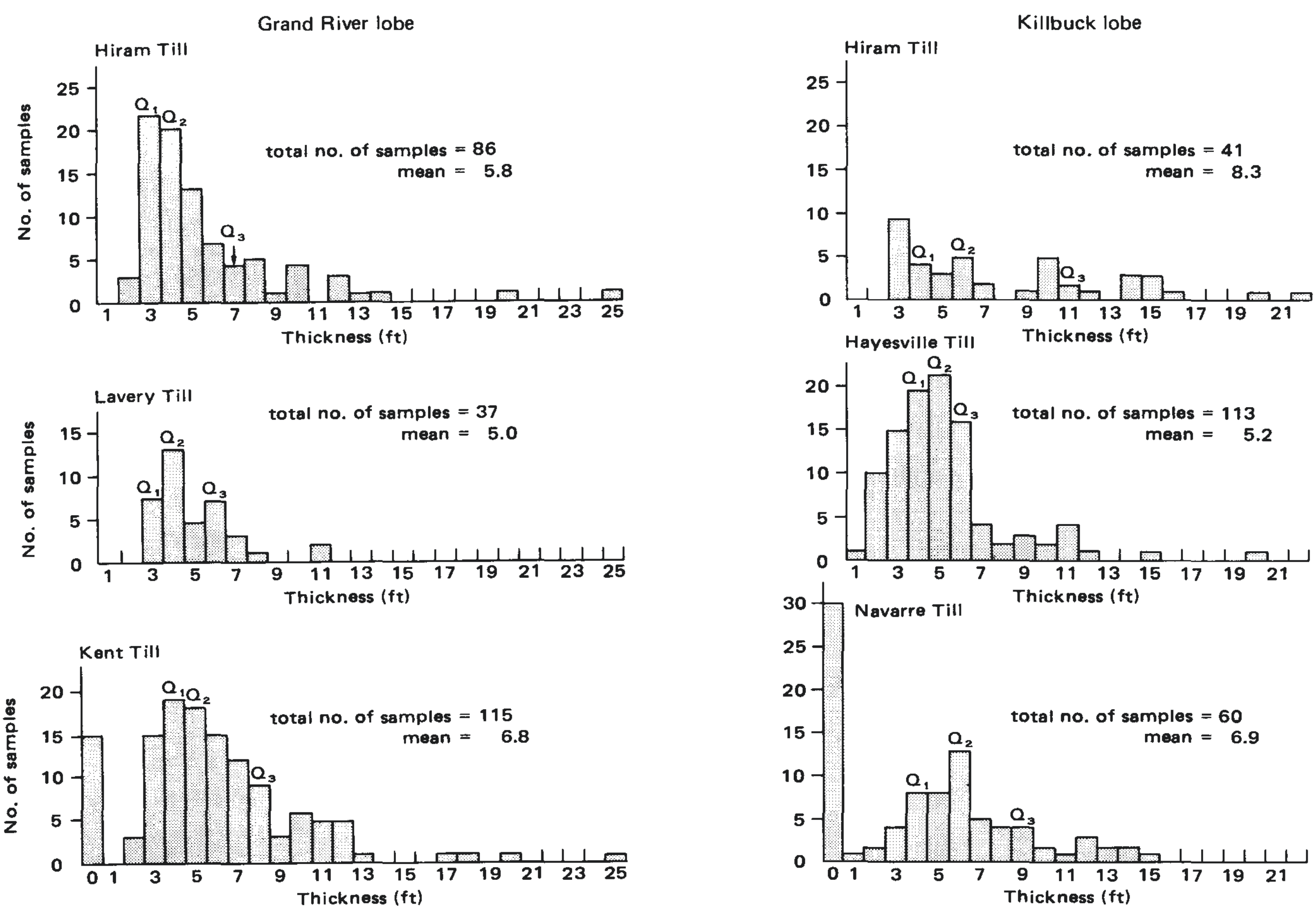


FIGURE 14.–Histograms of thicknesses of Woodfordian (late Wisconsinan) tills (modified from White, 1971a, p. 153, fig. 3). Note that zero thickness (till absent) is shown only for Kent and Navarre Tills. Quartiles (Q) and means for these two tills were calculated with zero thickness excluded. (Editor's note: an apparent error in the original figure was repeated here rather than alter the graph: Q_1 and Q_2 for the Hayesville Till in the Killbuck lobe are based on 24 and 28 samples, respectively, but are plotted incorrectly.)

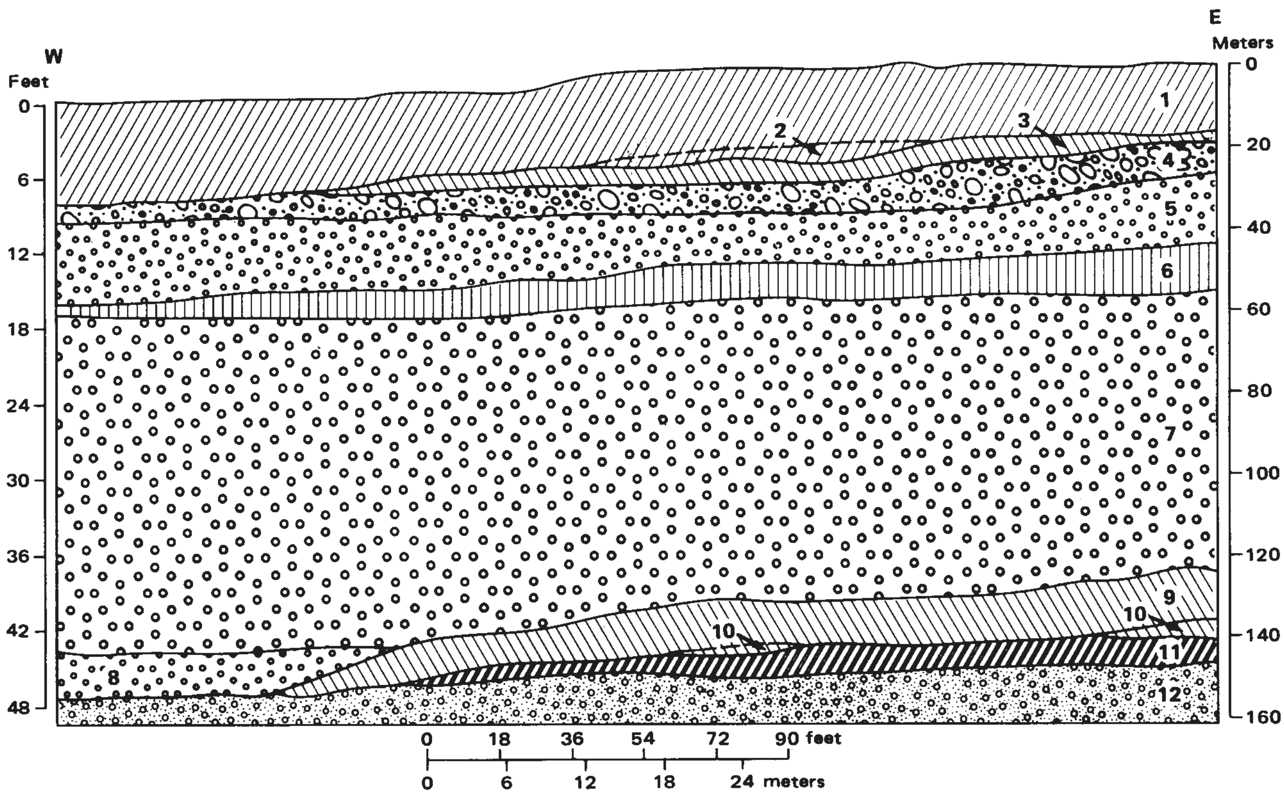
(1962). This older till has been preserved in a down-dropped block (the Elkton rift). The till is much disturbed, by tectonic movement and probably also by thrusting by later ice movement.

There are a number of other occurrences of very old deposits in northeastern Ohio. A very deeply weathered till, once exposed in a buried valley in a strip mine near New Springfield, Mahoning County (Totten, Moran, and Gross, 1969), about 15 miles north-northeast of Elkton, may be of the same age as the till at Elkton. The basal till in the more than 200-foot-deep buried early Grand River valley at Austinburg, Ashtabula County, where the Painesville Moraine has filled the valley and obliterates it, may be Kansan. Terraces in the Ohio River valley at East Liverpool, Wellston, and farther downstream at elevations of 960-1,020 feet have been studied in detail by Lessig (1959). The upper terraces of very deeply leached gravel may be Kansan in age (fig. 8). Deeply weathered till and outwash below Illinoian till and gravel (fig. 15) have been exposed from time to time in the deep gravel pit of the Derwacter Sand and Gravel Co., 1½ miles northwest of Bellville, Richland County (Totten, 1973). This till may be Kansan in age. Much-weathered till underlies several other weathered tills and boulder pavements, all below Millbrook Till, in NE¼ sec. 33, Blooming Grove Township, Richland County.

All of these deeply weathered tills lying below Illinoian till may be correlative with the probable Kansan-age Slippery Rock Till of Pennsylvania. A long period of weathering, known as the Yarmouthian Interglacial Stage, followed the Kansan Stage, which ended about 690,000 years ago (Goldthwait, 1979). The weathered materials on these ancient tills are the preserved parts of buried paleosol and are interpreted as Yarmouthian in age.

ILLINOIAN GLACIAL STAGE

Pre-Wisconsinan till, much more extensive than Kansan till, can be traced from the surface outcrop in Pennsylvania (White, Totten, and Gross, 1969) into Ohio. This till, named the Mapledale Till, is interpreted as Illinoian in age. The Mapledale surface in the northeastern part of northwestern Pennsylvania is as much as 6 miles wide, but decreases in width southwest to Ohio, where its margin essentially coincides with that of the later Wisconsinan till across Columbiana and Stark Counties. The Mapledale Till is found as a distinctive subsurface till at many places in Columbiana,



1. Till, olive-brown, deeply weathered, pebbly. MILLBROOK
2. Till, olive-brown, calcareous. MILLBROOK
3. Till, dark-reddish-brown, much-weathered. BUTLER
4. Gravel, strong-reddish-brown, coarse, cobbly, much-weathered; few boulders
5. Gravel, gray-brown, calcareous; as above
6. Till, gray, hard, pebbly, calcareous. ILLINOIAN
7. Gravel, gray-brown, sandy, even-bedded, calcareous. ILLINOIAN outwash
8. Gravel, gray-brown, coarse, calcareous
9. Till, dark-yellow-brown, pebbly, hard, calcareous; 39% sand, 21% clay. BUTLER
10. Till, gray-brown; as above. BUTLER
11. Till, strong-olive-brown, very pebbly, weathered; limestone thoroughly rotted. Pre-ILLINOIAN
12. Gravel, dark-reddish-brown, sandy, weathered; limestone ghosts. Pre-ILLINOIAN outwash

FIGURE 15.–Sketch of glacial deposits exposed in deep pit of Derwacter Sand and Gravel Co., NW¼NE¼ sec. 5, Jefferson Township, Richland County, 1½ miles northwest of Bellville (modified from Totten, 1973, p. 14, fig. 8).

Stark, and Summit Counties and at places in other counties in northeastern Ohio. The Butler Till in the Killbuck lobe is considered to be the correlative of the Mapledale and is assigned an Illinoian age.

PRE-MAPLEDALE AND PRE-BUTLER ILLINOIAN TILLS

At a very few localities a till lies below Mapledale Till and differs from it, but does not have any preserved weathering profile. Such early till was exposed in an excavation for I-76 northwest of Barberton, Summit County.

In Richland County, Totten (1973, p. 17) found that:

> At many of the same localities where Butler Till is exposed, additional till units are found beneath the Butler Till, separated from it by stone pavements or silt and sand layers . . . . These units can be grouped into two tills which are similar to, but older than, the Butler Till. However, they are not greatly older as no well-developed paleosol occurs between them and the Butler Till. These tills indicate that the Illinoian glacial stage was multiple, and that thick outwash sand and gravel deposits collected in the major valleys.

At a very few outcrops in Wayne County there is some indication of multiple tills of pre-Millbrook age (White, 1967, p. 16, fig. 5). The presence of these very scattered early tills throughout northeastern Ohio and northwestern Pennsylvania (White, Totten, and Gross, 1969, p. 16, fig. 26) below more extensive Mapledale or Butler Tills indicates that the Illinoian glaciation did not consist of a single episode of ice advance, but that more than one advance took place in Illinoian time. Such multiple Illinoian advances are well documented in the Mississippi Valley (Willman and Frye, 1970, fig. 1).

MAPLEDALE TILL

Location and extent

The Mapledale Till is found in some deep excavations and is encountered in drilling in the Grand River lobe. It is very discontinuous and appears to be preserved only in deep valleys and depressions of the bedrock surface (fig. 10). In some strip mines in Columbiana, Mahoning, and Stark Counties, coarse bouldery till resting upon the bedrock is interpreted as Mapledale (fig. 16). In Summit County the Mapledale Till crops out in deep excavations, such as the one on Gilchrist Road in East Akron (fig. 17), in the base of the pit of the Rubber City Sand and Gravel Co. in Green Township, and in the Alden gravel pit in Northampton Township. In Ashtabula County, till lying below several tills of Wisconsinan age is encountered in drill cores in the deep buried early Grand River valley at Austinburg. This till may be of Illinoian age.

Composition

The Mapledale Till is very hard and compact. The matrix is very sandy. Most of the boulders and cobbles are angular fragments of sandstone and siltstone. The sand fraction of the Mapledale Till in Pennsylvania has a mean composition of 95 percent quartz and 5 percent feldspar (White, Totten and Gross, 1969, p. 17). On the basis of only a few analyses, the Mapledale Till in eastern Ohio appears to have a similar composition. The Mapledale Till is noncalcareous or only weakly calcareous. The carbonate content is probably less than 1 percent.

Weathering character

Unoxidized Mapledale Till ranges from dark gray to olive gray. The oxidized till ranges from yellow brown to olive brown. Strong rust stains coat the prominent joint surfaces. Because the Mapledale Till does not occur at the surface in Ohio as it does in Pennsylvania, the depth of leaching and oxidation in Ohio cannot be determined. At no outcrop observed in Ohio is the complete weathering profile preserved below overlying till (for Pennsylvania see White, Totten, and Gross, 1969, p. 18, fig. 3).

Stratigraphic position

The Mapledale Till underlies the Titusville-Mogadore-Millbrook Tills of early Wisconsinan age. It lies upon bedrock, or at a very few places upon what appears to be an earlier Illinoian till, which may in turn overlie still earlier (Kansan?) till.

Age and correlation

The Mapledale Till in northeastern Ohio is correlated with the Mapledale Till of northwestern Pennsylvania by direct tracing. It is also correlative to the Butler Till of Richland County because of its similar stratigraphic position. In many places in Pennsylvania and at a few places in Ohio the upper part of the Mapledale Till is deeply weathered and is covered by remnants of a paleosol, considered to be Sangamonian in age (fig. 16).

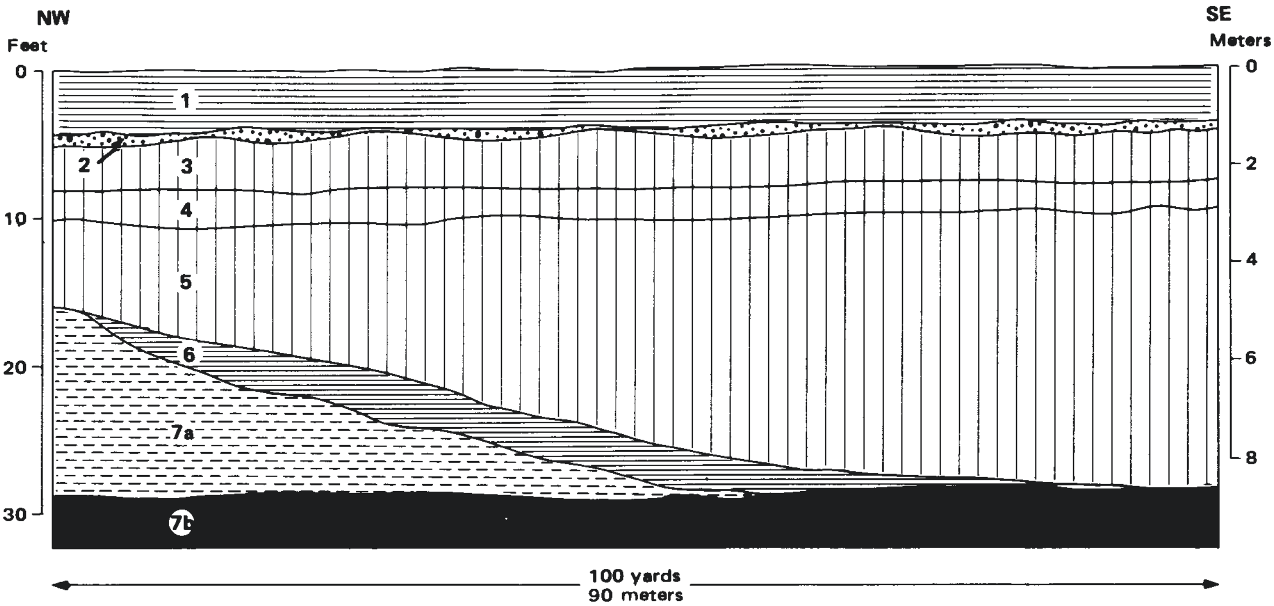
BUTLER TILL

Location and extent

A till at the surface in the Killbuck lobe in southern Worthington and Jefferson Townships, Richland County, and in southwestern Ashland County is mapped as Butler Till (Totten, 1973, p. 15). This area is hilly and the drift is extremely sparse and discontinuous. Leverett (1902) regarded this tract as driftless, but later detailed examination by White (1937, p. 12) disclosed the presence of very discontinuous thin till. This till has been described in more detail by Totten (1973, p. 15-17). At outcrops that extend to bedrock in Holmes, Richland, Ashland, and Wayne Counties, Butler Till lies below later Millbrook and other tills. At some of these outcrops, Butler Till may be thick enough to preserve unaltered gray till. Weathered zones and even part of a soil profile are preserved in a few outcrops (fig. 18; see also Totten, 1973, fig. 10; White, 1967, p. 12-16, figs. 4, 5; 1973; 1977).

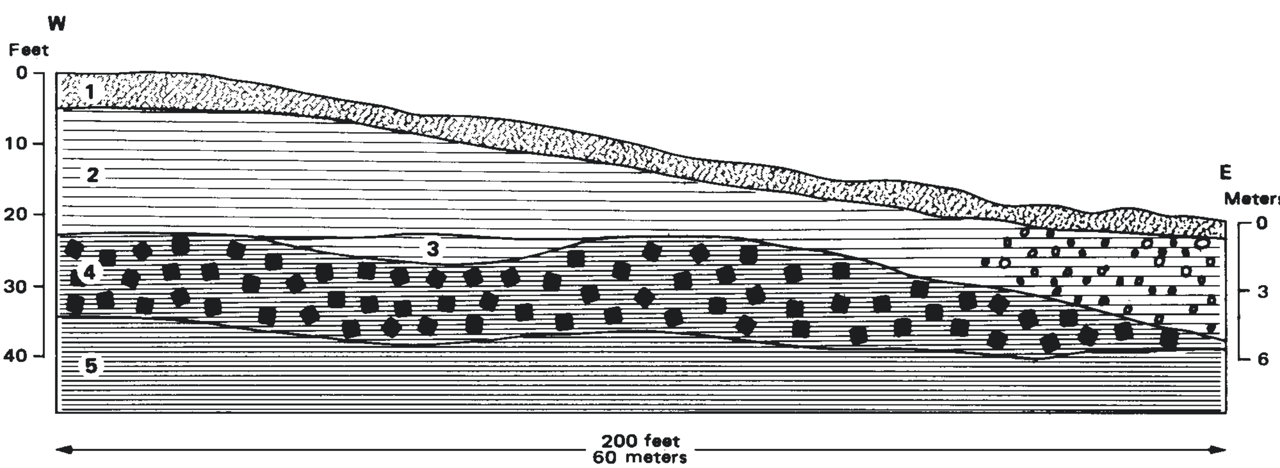
Composition

The Butler Till is sandy, silty, and pebbly. It is moderately calcareous; one sample from Richland County contained 9 percent carbonate (Totten, 1973, p. 17). Carbonate content decreases eastward; at one locality in Wayne County the Butler Till is only weakly calcareous and very compact (White, 1967) and resembles Mapledale Till in texture and composition.



1. Till, yellow-brown, much weathered at top. KENT
2. Colluvium, stones and pebbles, iron cemented; pedisediment. FARMDALIAN
3. Till, olive-brown, sandy, stony, noncalcareous. TITUSVILLE
4. Till, olive-brown, sandy, stony, calcareous. TITUSVILLE
5. Till, olive-gray, sandy, stony, calcareous; 47% sand, 20% clay. TITUSVILLE
6. Till, much-weathered, hard, noncalcareous, mixed with colluvium. MAPLEDALE
7. Bedrock, shale (7a) and coal (7b)

FIGURE 16.–Sketch of tills in strip mine, SE¼SW¼ sec. 1, Center Township, Columbiana County, 2 miles north-northeast of Lisbon.



1. Soil and weathered till
2. Till, yellow-brown to olive-brown, sandy; grades into cobby gravel to east. MOGADORE
3. Till, bright-gray, sandy, coarse, calcareous. MOGADORE
4. Till, almost all sandstone blocks. MAPLEDALE
5. Till, brownish-gray, sandy, fresh but noncalcareous. MAPLEDALE

FIGURE 17.–Sketch of section exposed in excavation for parking lot on the north side of Gilchrist Road just west of the I-76 underpass, East Akron, 2½ miles north-northwest of Mogadore, Summit County.

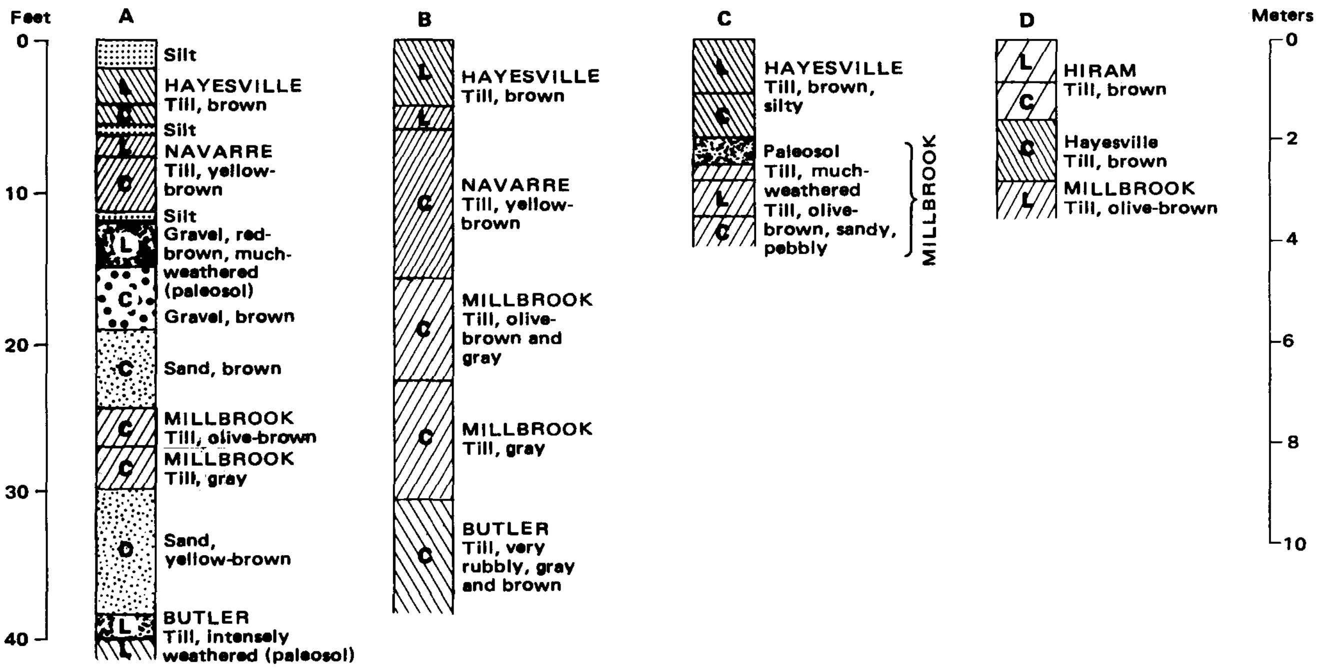


FIGURE 18.–Sections of tills in Ashland County showing Illinoian and Wisconsinan drifts (modified from White, 1977, fig. 3). A, excavation north of relocated U.S. Route 30, ¾ mile north of Mifflin; B, excavation in center sec. 2, Mifflin Township; C, auger hole in center sec. 11, Vermillion Township; D, roadcut in SW¼ sec. 15, Jackson Township. *L*, leached; *C*, calcareous.

Stratigraphic position

The Butler Till underlies the Millbrook Till of early Wisconsinan age. It lies upon bedrock or at a few places upon a still earlier till, which is believed to be of Illinoian age earlier than Butler.

Age and correlation

The Butler Till is correlative with the Mapledale Till of the Grand River lobe and is Illinoian in age.

DISTINCTIVE ILLINOIAN DRIFT IN CUYAHOGA, GEAUGA, AND PORTAGE COUNTIES

A very distinctive drift of Illinoian age appears to be confined to Cuyahoga, Geauga, and Portage Counties. The material is noticeably high in limestone and crystalline pebbles in contrast to other gravels and tills, which contain fewer limestone and crystalline pebbles (for a comparison see Winslow and White, 1966, table 4).

Almost 100 feet of till and gravel beneath several Wisconsinan tills are well exposed in a cut bank of Swine Creek, 1 mile northwest of Bundysburg, Geauga County, between the creek and the tracks of the Baltimore and Ohio Railroad (Baker, 1957, p. 7-9). The till is sandy, silty, very compact, and very pebbly; 32 percent of the pebbles are carbonates and 17 percent are crystallines. Very discontinuous oxidized till is present above the gray till.

In Cuyahoga County a similar distinctive till containing an abundance of carbonate and crystalline pebbles and cobbles crops out in a few places. At places this till is represented by gravel of the same distinctive composition (Winslow, White, and Webber, 1953, p. 36-39). The gravel, more than 60 feet thick, provided large quantities of high-grade gravel in a series of pits (now mostly abandoned) in the Mill Creek valley (Leverett, 1931, pl. 17-A; p. 126-127).

A distinctive highly carbonate and crystalline gravel at a large gravel pit (now abandoned) in southeast Ravenna, Portage County, is similar to the gravel described in Geauga and Cuyahoga Counties (Winslow and White, 1966, p. 20-21, fig. 8).

The relation of this distinctive highly carbonate and crystalline drift to the Mapledale and Butler Tills is not understood. It may be the deposit of an Erie lobe that only extended a few miles south of Lake Erie, but if so, are there Mapledale equivalents below? The possibility of Illinoian till above is ruled out by the presence of a thick paleosol above the gravel in the Mill Creek valley in Cuyahoga County, indicating that no later Illinoian deposit lies upon the gravel.

SANGAMONIAN INTERGLACIAL STAGE

The Sangamonian Interglacial Stage was a time of weathering and erosion and is recorded in weathered material upon the till and gravel of Illinoian age. In an abandoned gravel pit in the Mill Creek valley near Garfield Heights, Cuyahoga County, a complete soil profile is present on Illinoian gravel and below material of Wisconsinan age. Loess deposits on the paleosol preserved it from later erosion (fig. 19). This unique exposure has been described by White (1953, 1968) and Winslow, White, and Webber (1953, p. 36).

Weathered material of Sangamonian age is preserved in many places on top of the Mapledale Till in western Pennsylvania (White, Totten, and Gross, 1969, p. 13) and is present in at least one exposure in every county of the study area. Very rarely is a complete weathering profile preserved. Horizon 3, the leached and oxidized material, may be preserved, and at some places only horizon 4, the oxidized material, is preserved. Typical buried truncated Sangamonian profiles are illustrated in figures 10, 15, 16, 18, and 19.

The weathered material of Sangamonian age on top of the Butler Till has been described in Ashland (White, 1977, fig. 3A), Richland (Totten, 1973, p. 17-19, figs. 10, 11, 14), and Wayne (White, 1967, p. 12-16, fig. 6, section 1780) Counties. Some of these profiles are illustrated in figures 15 and 18.

In addition to weathering of the Illinoian till and other deposits, much stream erosion took place in Sangamonian time. Large areas of Illinoian till were reduced in thickness and even removed, especially in the more hilly parts of northeastern Ohio. Some of the valleys cut into Illinoian till were later filled with stream deposits, colluvium from slope movements, or proglacial outwash of the advancing Wisconsinan ice. These deposits were then covered by later till deposits and are not evident at the present surface.

WISCONSINAN GLACIAL STAGE

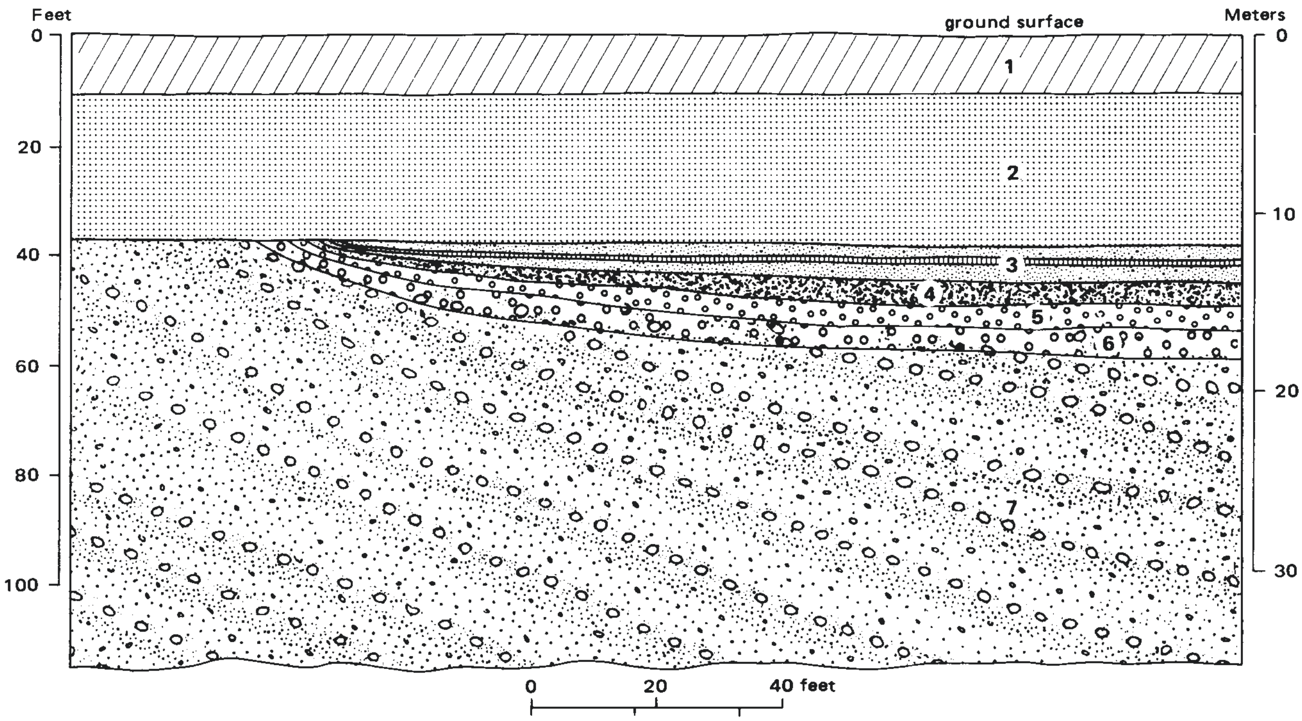
The latest stage in the Pleistocene Epoch is the Wisconsinan Stage (table 2). It is divided into an earlier Altonian Substage and a later Woodfordian Substage. Later substages are known north of Ohio, but need not be discussed here (see Willman and Frye, 1970, fig. 1).

There is some indication of Wisconsinan glaciation earlier than Altonian. A till in extreme northeastern Ohio, the Keefus Till, is older than the Titusville Till of Altonian age and is tentatively assigned an earliest Wisconsinan age, probably pre-Altonian.

KEEFUS TILL

Location and extent

The Keefus Till is named for an exposure (fig. 20) on the north bank of Conneaut Creek, 50 yards east of the Keefus Road bridge across the creek, in Conneaut Township, Ashtabula County (White and Totten, 1979). It is a distinctive red till which crops out below later tills at several places in northern Ashtabula County. The Keefus Till has been noted at two places 15 miles south of Lake Erie in central Ashtabula County, but has not been observed as far south as Trumbull County. A red till has been recorded in logs of 12 water wells drilled between 1970 and 1974 in northern Ashtabula County and from several wells in Lake



1. Till. HIRAM (possibly some LAVERY in basal part)
2. Varved silt. POST-FARMDALIAN
3. Loess; weathered zone in middle. FARMDALIAN
4. Paleosol. SANGAMONIAN
5. Gravel, leached
6. Gravel, oxidized
7. Gravel, gray, sandy; 40 feet exposed, total reported thickness 90 feet. ILLINOIAN

FIGURE 19.—Sketch of Farmdalian loesses and Sangmonian paleosol overlying Illinoian gravel exposed in pit of Cleveland Sand and Gravel Co., 1 mile southeast of Garfield Park, Cleveland (modified from Winslow and White, 1953, pl. 25).

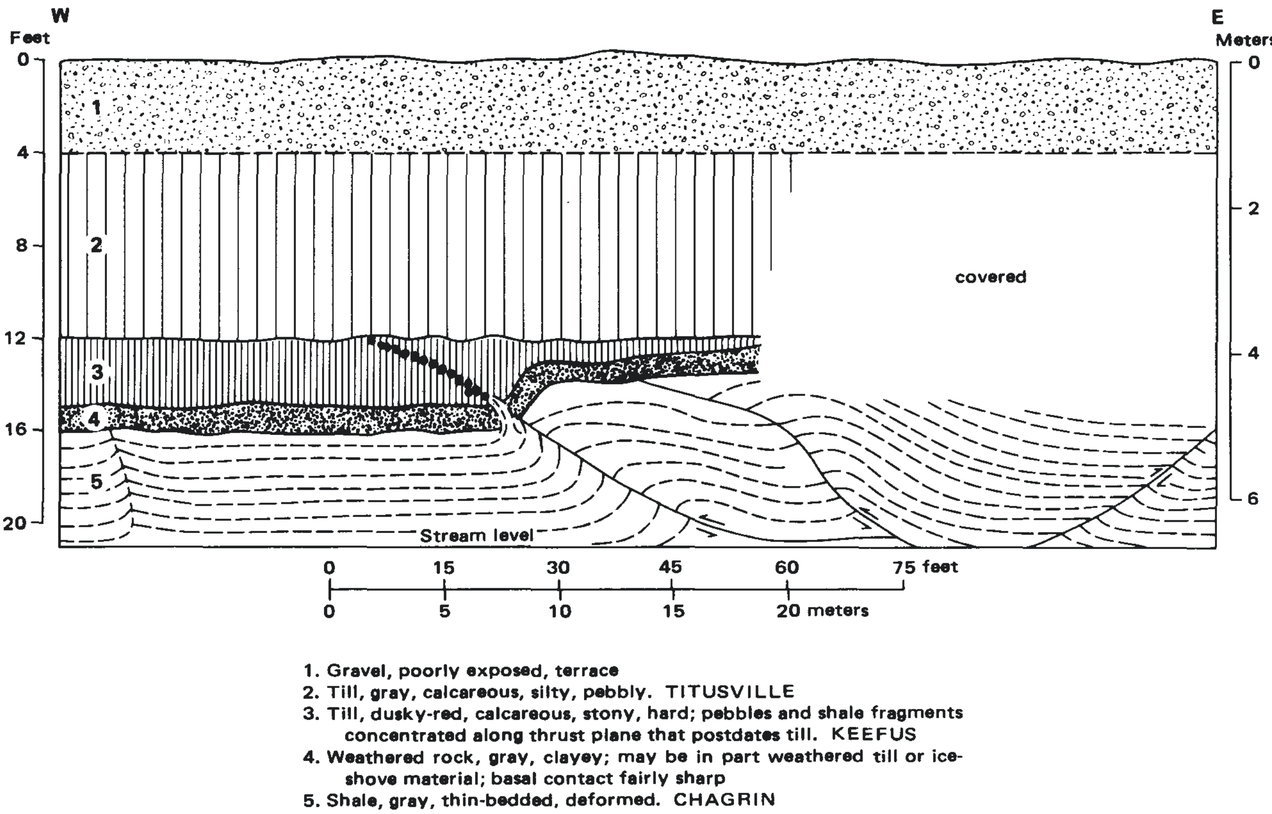


FIGURE 20.–Sketch of the type section of the Keefus Till exposed in the north bank of Conneaut Creek 50 yards east of the Keefus Road bridge (and the U.S. Geological Survey gaging station), Conneaut Township, 0.6 mile east of Amboy, 2.7 miles southwest of the town hall in Conneaut, Ashtabula County (from White and Totten, 1979, p. 10, fig. 9).

County. It is apparent, therefore, that the red Keefus Till extends discontinuously at least 20 miles south of Lake Erie and at least 45 miles west of the Pennsylvania-Ohio state line. How much farther this subsurface unit extends is not known.

The original thickness of the Keefus Till also is not known because the upper surface is always eroded. A thickness of 15 feet was recorded from one water well.

At the type locality the Keefus Till and the underlying Devonian Chagrin Shale Member are faulted; the Titusville Till truncates the fault (fig. 20), thus establishing the age of the fault as pre-Titusville. It cannot be determined if the fault is the result of ice shove or some other cause; an excavation of a few feet would help determine the character of the fault at deptn.

Composition

The Keefus Till is very hard and dusky red or reddish gray to reddish brown. The red color is not the result of weathering, but its origin is not yet understood. The Keefus Till is very stony, with small pebbles and small cobbles, and is everywhere calcareous, indicating that a considerable thickness of the upper part of the till has been eroded. The Keefus Till is sandier than the Ashtabula, Hiram, or Lavery Till and has a lower clay content.

Stratigraphic position

The Keefus Till is underlain either by bedrock or by earlier much-weathered till. It is overlain by Titusville Till at the type locality; younger tills have been eroded and replaced by terrace gravel.

Age and correlation

The age of the Keefus Till cannot be precisely assigned as yet. It is definitely older than the Titusville Till, which overlies it. Thus, it can be no younger than earliest Wisconsinan. It could be late Illinoian, but at no place has any paleosol been observed upon it, and at present an early Wisconsinan, probably pre-Altonian age, is preferred. The Keefus Till may be the correlative of the Bradtville Till, the earliest Wisconsinan till of western Ontario (Goldthwait and others, 1965, p. 92).

ALTONIAN SUBSTAGE

Terminology

The presence of drift older than Woodfordian (late Wisconsinan) north of the fringe area in Columbiana and Stark Counties was recognized in northeastern Ohio in the southern half of Summit County. It was first named "Tazewell," and the age assignment was early Wisconsinan-Tazewell (Smith and White, 1953, p. 18). This till was later named the "Mogadore Till" (White, 1960, p. A3-4) for the village of Mogadore, 1 mile east of the type section exposed above the bedrock in the shale pit of the Universal Clay Products Corp. in Springfield Township, Summit County.

This till was recognized in the subsurface in adjacent counties (White, 1960, p. A4).

Later work in the Grand River lobe in northwestern Pennsylvania, more than 100 miles east and northeast of Summit County, Ohio, disclosed the presence of a belt of older till, which was at first called Inner Illinoian (Shepps and others, 1959). Still older till in a belt to the east was called Outer Illinoian and was later named "Mapledale." This till was definitely much more eroded and weathered than the Wisconsinan till to the west. The till formerly called Inner Illinoian was named "Titusville" for the type section near Titusville, Pennsylvania (White and Totten, 1965). Wood found in association with this till had a carbon-14 date of about 40,000 years before present (B.P.) (White, Totten, and Gross, 1969, p. 30). This date showed that the Titusville Till is of Wisconsinan age rather than Illinoian and is correlative in age with Altonian-age tills in Illinois. It was suspected that the Titusville Till was correlative with the Mogadore Till in Summit County, but the distance between these areas was so great that the separate rock-stratigraphic names were preferred.

Later work throughout northwestern Pennsylvania (White, Totten, and Gross, 1969) showed that the Titusville Till throughout most of the area in which the surface material was Woodfordian drift actually composed the major part of the drift column. The extension of the field study from western Pennsylvania into eastern Ohio showed that Titusville Till could be traced into Columbiana, Mahoning, and Trumbull Counties (White, 1971b; White and Totten, unpublished work). The Titusville Till was traced farther west from these counties into Stark and Portage Counties, where it became evident that the Mogadore Till traced from the outcrop eastward was indeed correlative with the Titusville Till.

Work in Ashland and Wayne Counties (White, 1977, 1967) in the Killbuck lobe disclosed the general presence of a coarse sandy till earlier than tills of Woodfordian age. This till was believed to be a correlative of the Mogadore Till, but had not been traced in the subsurface; the till was named "Millbrook Till" for Millbrook, Plain Township, Wayne County (White, 1961). Later work (White, unpublished work) confirmed the suspicion that the Millbrook Till was traceable eastward to Summit County and was indeed correlative with the Mogadore Till.

Inasmuch as tills of the same approximate age in different lobes may be somewhat different in composition and may not be strictly synchronous in deposition, it is generally preferred by Pleistocene stratigraphers to use different rock-stratigraphic names in different lobes, but to point out the correlative terms in other lobes. Although the term "Titusville" has now assumed wide usage in Pleistocene stratigraphic literature, it is actually a term applicable only to Altonian-age till of the Grand River lobe. As the Altonian-age till in Summit County is in the small Cuyahoga lobe between the Grand River and Killbuck lobes, the name "Mogadore Till" remains appropriate for that till. The Killbuck-lobe till is the Millbrook Till and the Scioto-lobe equivalent is the Jelloway Till.

The Titusville-Mogadore-Millbrook-Jelloway episode of glaciation produced two contrasting types of deposits. South of a line at the southernmost margin of a series of end moraines, a little north of the middle of Summit County (pl. 1; fig. 6), the deposits consist of ground moraine on most uplands and hummocky areas of thicker drift along valley sides. These hummocky areas have no linear trend. The valleys are occupied in part by kames and kame terraces. The Altonian drift is markedly hummocky in the southeastern part of Summit County and the deposits consist of a high proportion of gravel aggregated in a conspicuous kame moraine. In northern Summit County and in the counties to the west, the deposits are much different; the Altonian drift is aggregated in a series of linear belts or end moraines. The belts are discrete entities to the west, but in central and eastern Medina County and in Summit County these belts are compressed into a confused aggregate of hummocky topography 5 to 8 miles wide. In extreme northern Summit County the Defiance Moraine is a separate and definable ridge. The Defiance Moraine represents a readvance of the Titusville-Mogadore-Millbrook-Jelloway ice and a different type of deposition from the earlier one. How much time intervened between the two advances is not known.

Titusville Till

Location and extent.—The Titusville Till is the oldest till present on the surface in the Grand River lobe in northeastern Ohio, although it is mainly a subsurface till below drift of later age. The type locality is at Titusville, Pennsylvania (White and Totten, 1965; White, Totten, and Gross, 1969, p. 23-32), from where it has been traced into Columbiana County, Ohio. The Titusville Till is present at the surface in a belt ranging from 2 to 4 miles wide across the central part of Columbiana County and the southeastern part of Stark County. The southern margin of this till is the glacial boundary.

At some places where the Titusville Till is the surface material it is so thin that all the till is incorporated in the present soil, with only a few pebbles and cobbles on the surface to indicate the presence of some glacial material. This is particularly the case in the outer marginal part of the belt, except where large kames are massed along the boundary. At other places, generally a mile or more north of the southern limit, pockets of Titusville Till are as much as 10 feet thick, and a few are more than 20 feet thick.

North of the belt of outcrop and below later tills, the Titusville Till has a mean thickness of 20.2 feet (table 6) and is composed of as many as three sheets (fig. 21). The Titusville Till in the subsurface is by far the thickest till in northeastern Ohio and composes the bulk of the glacial drift in the Grand River lobe under a cover of generally thin later material. To the east and northeast in Pennsylvania the Titusville Till is composed of as many as five separate sheets (White, Totten, and Gross, 1969, p. 27-29, figs. 17-30). These till sheets are interpreted to be the result of deposition by ice which readvanced several times, with each readvance reaching less far than the preceding one. The Kent Moraine is believed to be the zone along which the Titusville Till sheets were stacked to form the major volume of this feature.

Composition.—The Titusville Till is coarse, sandy, and stony. This till is hard, compact, dense, and picks with some difficulty; the matrix retains the imprint of pebbles after they are removed. The mean texture of the matrix in Columbiana County is 49 percent sand, 32 percent silt, and 19 percent clay; in the Grand River lobe as a whole in Ohio and Pennsylvania the mean texture is 45 percent sand, 37 percent silt, and 18 percent clay (table 3). In Columbiana County the feldspar content ranges from 4 to 10 percent and the quartz content from 90 to 96 percent, but the means for the Grand River lobe as a whole are 13 percent and 87 percent, respectively. The general southward decrease in feldspar content in the Titusville Till in the Grand

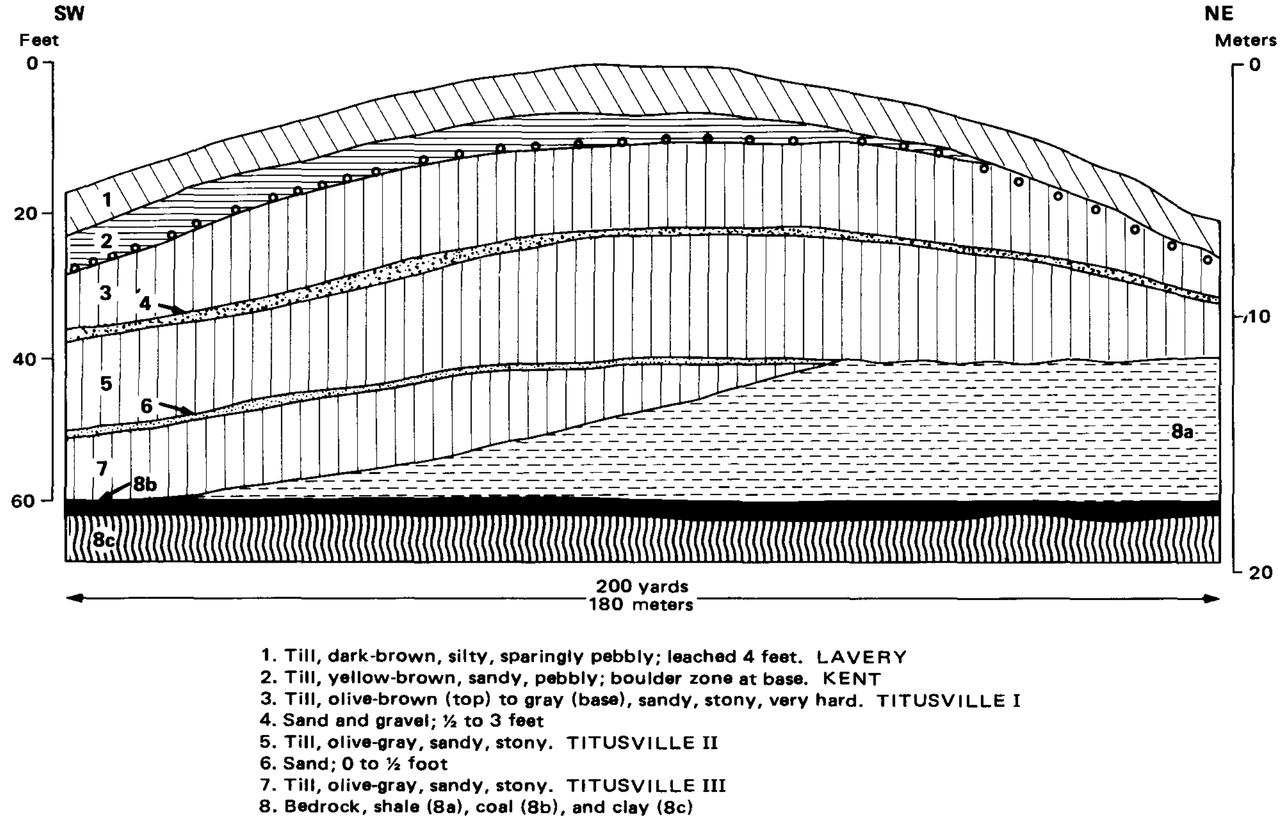


FIGURE 21.–Sketch of multiple Titusville tills forming the bulk of the Kent Moraine in an exposure in clay pit of Whitacre-Greer Co., SW¼NE¼ sec. 7, Knox Township, Columbiana County.

River lobe has been investigated in detail by Gross and Moran (1971, fig. 2). The Titusville Till reacts visibly to hydrochloric acid; the mean carbonate content is about 3 percent.

Weathering character.–Unweathered Titusville Till is olive gray. Where the Titusville Till is at the surface there are only a few outcrops thick enough to preserve unweathered gray till, but at those few places the gray till is 12 to 20 feet below the surface. In the subsurface, gray till is common. The upper part of the Titusville Till has been oxidized along joints and horizontal partings; at outcrops exposed to the air for some time these partings become somewhat harder and present a characteristic reticulated appearance. The oxidized Titusville Till is olive brown with heavy, dark stains along the joints and around pebbles. The olive-brown color contrasts with the yellow brown of the younger Kent Till. The upper part of the Titusville generally shows disturbance and colluviation, and the soil may be formed in colluvium rather than in till. The depth of leaching therefore is variable, but ranges from 7 to 11 feet. The weathering of the Titusville Till yields a well-drained friable soil mapped as Hanover on drift-mantled slopes or as Loudonville on steeper slopes or other areas where little drift remains (for details see Lessig and others, 1968).

North of the belt of surface outcrop, where later tills overlie Titusville Till, truncated weathering profiles are present in some places. A complete paleosol has not been discovered, because at all exposures at least some of the upper part has been removed. At a few places where the paleosol is preserved it is a very hard dark-reddish-brown clay loam, the lower part of which contains many fragments of angular sandstone and siltstone (channers) as much as 3 inches in length. Such material is ascribed to translocation, colluviation, and pedisediment action (White, 1967, p. 21; White, Totten, and Gross, 1969, p. 27).

Stratigraphic position.–The Titusville Till is underlain by weathered Mapledale Till in a few places, or by bedrock. North of the Kent Till margin the Titusville Till is overlain by Kent Till, but in some places the Kent Till is missing and Titusville Till is at the surface. Farther north, where the Kent Till is missing Lavery Till lies directly on Titusville Till.

Where it is at the surface the Titusville Till appears to consist of a single sheet. North of the area of outcrop the Titusville Till commonly consists of two or more units (fig. 21) separated in most places by sand and gravel, sometimes of considerable thickness. These intertill layers may be water bearing, and thus the stability of slopes in strip-mine, highway, and other deep cuts may be affected. The multiple-unit character of the Titusville Till may be indicated not only by the presence of the sand and gravel layers, but also by a change in color from olive gray to a brighter gray. The multiple units stand out sharply on the faces of many excavations.

Age and correlation.–The Titusville Till has been traced into northeastern Ohio from its type locality at Titusville, Pennsylvania, about 80 miles northeast of Columbiana County, Ohio. The age of the Titusville Till, determined from carbon-14 analyses of peat associated with the till at

Titusville, is about 40,000 years (White, Totten, and Gross, 1969, p. 30). It is, therefore, Altonian (early Wisconsinan) in age in terms of the Mississippi Valley classification (Willman and Frye, 1970). The earlier assignment of an Illinoian age (White, 1951) was based on degree of weathering and erosion, which was greater than that of the tills of unquestioned Wisconsinan age to the north. The existence of an early Wisconsinan till was not realized at that time, so any till older than that to the north was perforce Illinoian.

The Titusville Till has been traced in the subsurface through the Grand River lobe. It is correlative with the Mogadore Till of the Cuyahoga lobe, the Millbrook Till of the Killbuck lobe, and the Jelloway Till of the Scioto lobe (Totten, 1973). The various Titusville till sheets are interpreted to be a result of deposition by ice which readvanced several times, but with each readvance reaching less far than the earlier ones.

Titusville outwash

Kames.—Associated with the Titusville Till in many places are deposits of gravel in the form of kames, some of them large and extensive. Some of the kames are in the area of Titusville outcrop, and others are buried, in whole or in part, beneath later till in the region north of the outcrop belt.

In part of the Grand River lobe north of the Titusville outcrop belt, extensive areas within the Kent Moraine and to a less extent elsewhere are Titusville kames, with gravel exposed at the surface or with only a thin cover of later drift. Where the cover is thicker, borings and well records reveal the presence of buried gravel. The extensive kame terraces in the valleys throughout the Grand River lobe are mainly composed of gravel of Titusville age with a very thin cover of later till.

Valley trains.—Meltwater flowing away from the waning Titusville ice eventually reached the Ohio River. Sand and gravel carried by these meltwater streams were deposited in the valleys to form valley trains. Later, erosion by the streams, no longer overloaded by glacial debris, cut floodplains below the valley-train levels and removed much of the sand and gravel, so that only remnants exist as terraces along the valley sides.

Titusville terrace remnants are present south of the glacial boundary, above the lower Kent terraces in the valleys of the tributaries of Little Beaver Creek in Columbiana County. Remnants are present in the valleys of Nimishillen Creek in Stark County and Sandy Creek in Columbiana and Stark Counties (DeLong and White, 1963, p. 149 and pl. 2, where the terraces are called Illinoian).

In the Ohio River valley, two extensive lower terraces lie below two higher early Pleistocene terraces. The Titusville terrace is the higher of these two lower terraces. This terrace was called Illinoian by Lessig (1961, fig. 1) and illustrated as the 770-740-foot terrace (Lessig, 1959, p. 337; fig. 8 of this report). The terrace remnants have an elevation of about 760 feet, some 50 to 60 feet above the lower Kent terrace. Equally large remnants of Titusville terraces are present near Columbiana County in a very large gravel pit at Georgetown, Pennsylvania; at Newell, West Virginia; and at Waterford Park, West Virginia. These terraces and the whole complex of Ohio River valley terraces deserve detailed study.

The Titusville gravels of the valley trains are generally leached 17 feet or more, whereas the Kent gravels are leached about 7 to 8 feet (Lessig, 1961, p. 289, 291). The soils on the Titusville terraces are of the Negley Series, those on the Kent terraces are of the Chili Series (Lessig and others, 1968, p. 79-80, 60-70).

Mogadore Till

Location and extent.—The Mogadore Till of the Cuyahoga lobe is named for the type locality near Mogadore, Summit County (White, 1960, p. A3-A4) and is the surface material in the southern half of Summit County (pl. 1). A few small thin patches of silty clayey Hayesville Till overlie the Mogadore Till in extreme western Summit County, but these are so inconspicuous that the surface material is over 95 percent (probably 99 percent) coarse Mogadore Till.

North of the surface outcrop the Mogadore Till continues in the subsurface throughout the northern half of Summit County and constitutes the main bulk of the drift in most places. The median thickness of the Mogadore Till is about 16 feet, but at many places it is much thicker. It is similar to the correlative Titusville Till in thickness.

Composition.—The Mogadore Till, similar in composition to the Titusville Till, is coarse, sandy, and stony. At the type locality the Mogadore Till contains 60 percent sand and 13 percent clay, but at most places the sand content is not over 50 percent and the clay content is not much less than 19 percent.

On the basis of the few available data the feldspar content is about 10 percent and the quartz content about 90 percent. It is probable that the feldspar content decreases and the quartz content increases from north to south (Gross and Moran, 1971, fig. 2). The Mogadore Till contains enough carbonate to react visibly with hydrochloric acid. On the basis of the few available data the carbonate content is about 4 percent.

Weathering character.—The weathering horizons of Mogadore Till are shown in figure 22. Unweathered Mogadore Till is olive gray. Oxidation has penetrated along the joints and horizontal partings in the upper part of the gray till, just as in the Titusville Till. The upper part of the Mogadore Till has been oxidized to an olive-brown color; this color contrasts with the yellow brown of the Kent Till and the dark brown of the Lavery and Hiram Tills. Conspicuous darker stains occur along joints and around pebbles. The matrix retains the imprint of pebbles after they have been removed. The Mogadore Till is very hard, compact, and picks with some difficulty. The depth of leaching at the type locality is 6 feet 10 inches, but elsewhere the depth of leaching ranges from 6 to 9 feet. Weathered Mogadore Till yields a friable soil, like that of the Titusville Till, of the Wooster Series in well-drained locations, the Canfield Series in moderately well drained locations, and the Ravenna Series in poorly drained locations (Ritchie and Steiger, 1974).

In the northern part of Summit County, where later tills overlie Mogadore Till, truncated weathering profiles of Farmdalian age are present in a few places, but no complete paleosol has been discovered. At a few places below later tills, the upper part of the Mogadore Till is a very hard red-brown clay loam, the lower part of which contains many fragments of sandstone and siltstone. This material is similar to that of the Titusville and Millbrook Tills at places throughout northeastern Ohio.

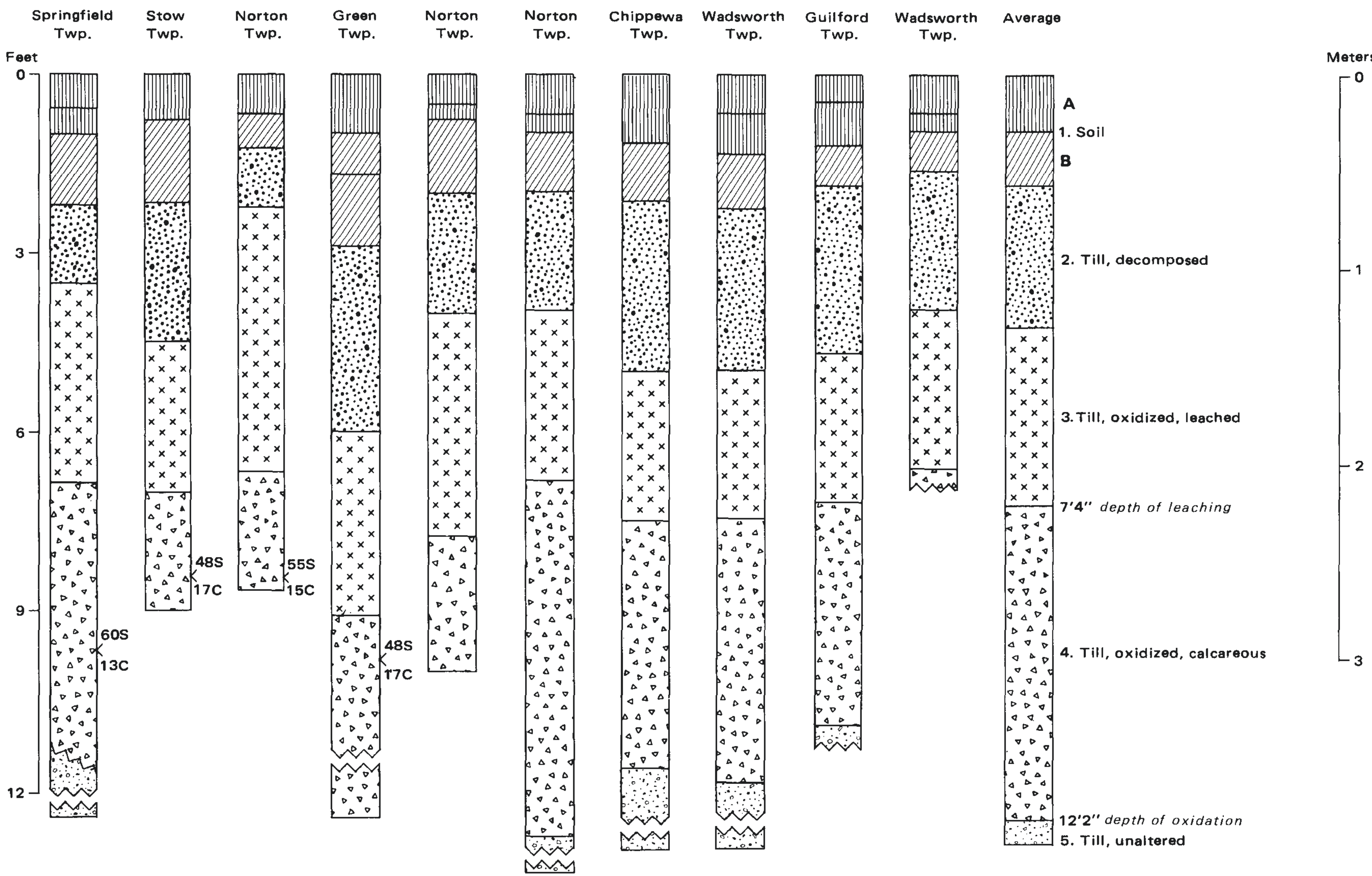


FIGURE 22.–Weathering horizons of Mogadore Till (modified from Winslow and White, 1966, p. 23, fig. 9). Chippewa Township section is from Wayne County; all others are from Summit County. Percentages of sand (S) and clay (C) shown for samples collected at indicated points.

Stratigraphic position.—The Mogadore Till generally is underlain by bedrock, or by Mapledale Till in a few places. In the northern part of Summit County the Mogadore Till is overlain by Kent Till in some places, but in other places the Kent Till is thin or missing, and Lavery Till lies directly on Mogadore Till. At perhaps half or more of the outcrops in northern Summit County the material directly over the Mogadore Till is Lavery Till.

Age and correlation.—The age of the Mogadore Till is based on its correlation with the Titusville Till. The age of the Titusville Till determined from carbon-14 analyses of peat associated with the till is about 40,000 years (White, Totten and Gross, 1969, p. 30). The Titusville and Mogadore Tills are therefore Altonian (early Wisconsinan) in age. Mogadore Till also is correlative with the Millbrook Till of the Killbuck lobe (White, 1967; Totten, 1973) and with the Jelloway Till of the Scioto lobe (Totten, 1973).

Mogadore Till is 20 to 30 miles north of the outer margin of Titusville Till in Stark and Columbiana Counties, so that the age assumption based on the Titusville determination can be only approximate. The somewhat shallower depth of leaching of the Mogadore Till may be due to a slightly younger age or to a slightly higher carbonate content than Titusville Till.

Mogadore outwash

Kames.—As shown on plate 1, a high proportion of the southern half of Summit County consists of kame deposits of Mogadore age. Large areas of Mogadore-age kames are buried beneath later drift in northern Summit County in Bath, Northampton, northern Stow, and southern Hudson Townships.

Valley trains.—In the lower parts of some of the valleys in southern Summit County, particularly in the Tuscarawas River valley south of Barberton, in parts of the Portage Lakes lowland, and in the lowlands surrounding the Copley Marsh, deposits of sand and some gravel are present. Some of these deposits are those of the last melting phase of Mogadore ice when meltwater flowed southward. However, some of the material is of later age, deposited by meltwater from the north when the Kent, Lavery, and Hiram ice was disappearing.

Millbrook Till

Location and extent.—The Millbrook Till of the Killbuck lobe is named for an exposure in SE¼ sec. 25, Plain Township, Wayne County, near the village of Millbrook, 4 miles southwest of Wooster (White, 1961, p. 71). It has been traced from Wayne County into Stark, Holmes, Ashland, and Richland Counties.

The Millbrook Till is the surface material only in parts of several townships in southern Richland County (Totten, 1973, p. 19; pl. 1) and an adjacent area of about a square mile in southwestern Ashland County. It is almost everywhere present below later tills throughout the Killbuck lobe. In the hilly area of surface outcrop the Millbrook Till is not continuous and at places is quite thin. Farther north, where the Millbrook Till is a subsurface unit, it is much more continuous, has a median thickness of 12.6 feet (table 6), and constitutes the bulk of the drift in the Killbuck lobe. In many places the overlying tills are thin or missing and the Millbrook Till predominates even in shallow outcrops.

Composition.—The Millbrook Till is weakly calcareous, sandy, and pebbly and contains many cobbles and boulders. Sandstone and coarse siltstone fragments are prominent. The content of the matrix ranges from 36 to 44 percent sand, 42 to 45 percent silt, and 15 to 19 percent clay (table 5). The carbonate content ranges from 3 to 9 percent. The feldspar content of the Millbrook Till is a bit higher than that of the Titusville and Mogadore Tills; it may be as much as 20 percent.

Weathering character.—As in the Titusville Till, the unweathered Millbrook Till is olive gray. The oxidized till is olive brown and has conspicuous darker stains along joints and around pebbles. It is very hard and compact. Where the Millbrook Till is at the surface in southern Richland County, the depth of leaching ranges from 6 to 11 feet; where it is in the subsurface, depth of leaching is generally 8 to 9 feet (Totten, 1973, p. 21). The Millbrook Till is deeply oxidized, and at almost all exposures where it is the surface material the oxidation extends to the base of the till.

Stratigraphic position.—The Millbrook Till is underlain by the Butler Till or by bedrock. It is overlain by the Navarre Till in most places, but in some places the Navarre Till is missing, and the Hayesville Till lies directly on the Millbrook Till (fig. 18).

Age and correlation.—The Millbrook Till is correlated with confidence to the Mogadore Till of the Cuyahoga lobe and the Titusville Till of the Grand River lobe because the three tills are so similar in appearance, composition, density, and stratigraphic position. As the age of the Titusville Till is about 40,000 years, as already discussed, the age of the Millbrook Till also is Altonian. The Millbrook Till is correlated by direct tracing with the Jelloway Till of the Scioto lobe.

Millbrook outwash

Part of the area of the Killbuck lobe consists of Millbrook-age kames and very extensive kame terraces in the valleys. Most of these kame deposits are north of the area of Millbrook outcrop and are covered by till of later age. In places the till covering is so thin that it is not immediately apparent. This situation corresponds to the similar situation of the extensive kames of the same age in the Cuyahoga and Grand River lobes.

Jelloway Till

A relatively small area in extreme southern Richland County and a tiny area in extreme southwestern Ashland County were glaciated by ice of the Scioto lobe (Totten, 1973, p. 29).

The Jelloway Till of the Scioto lobe was named by Totten (1973, p. 29) for exposures near the village of Jelloway, northern Brown Township, northeastern Knox County. The Jelloway Till has the same appearance and general composition as the Millbrook Till, which can be traced directly into it.

The Jelloway Till of the area of this report is the northern margin of a large area of Jelloway Till, which is the surface till through much of the eastern half of Knox County. This till was formerly called Illinoian (White, 1937, 1939; Root, Rodriguez, and Forsyth, 1961, p. 115-119, pl. 6; Goldthwait, White, and Forsyth, 1961). The present Altonian age assignment is made on the basis of tracing the

Jelloway Till directly into the Millbrook Till of the Killbuck lobe, which is interpreted as Altonian in age.

FARMDALIAN SUBSTAGE

Where later till overlies Titusville-Mogadore-Millbrook Tills, a weathered zone of paleosol is found in many places upon the lower till. This paleosol is typified in a section from Ashland County (fig. 18C). This weathered zone very rarely includes a complete soil profile because portions of the upper part have been removed by later glacial erosion. At some places only the lower part of the oxidized zone remains. One common evidence of weathering is the presence of very hard dark-reddish-brown clayey loam, ranging from 3 inches to almost 2 feet in thickness and containing many fragments of flat, angular sandstone and siltstone pieces (channers). This material is very evident in augering, as it is penetrated with extreme difficulty. It is regarded as an ancient colluvium upon the lower till and is sometimes referred to as pedisediment (White, 1967, p. 21).

Further evidence of weathering and erosion is present in a few places in Richland County. Clay-filled wedges extend 2 to 6 feet into gravel of Millbrook age (fig. 23). Gravel and till of later age overlie the Millbrook gravel with the clay wedges. These wedges may be permafrost features formed during a period of colder climate (Totten, 1973, p. 28, fig. 18).

This weathering occurred during the Farmdalian Substage, which at Cleveland extended from about 28,000 years to 24,000 years B.P. (White, 1968). The Farmdalian Substage is named for deposits and weathered materials near Farmdale, Illinois (Willman and Frye, 1970, p. 29, 81, 87), where the Farmdalian extended from 21,000 to 27,000 years B.P. This time corresponds approximately to the time of deglaciation, erosion, and weathering in Canada called the Plum Point Interstadial (Dreimanis and Goldthwait, 1973, p. 80, fig. 3, and references therein).

At almost all places in northeastern Ohio weathering took place after the deposition of the Altonian deposits. However, at a few places windblown silt—loess—was deposited in Farmdalian time. (Farther west, in Illinois, a great deal more loess was deposited at that time.) In two gravel pits in the Mill Creek valley on the southeastern margin of Cleveland, loess of Farmdalian age as much as 2 feet 6 inches thick overlies an older much-weathered loess of Altonian age, which in turn overlies 6 feet or more of humic gley, partly residual and partly colluvial, developed on thick Illinoian gravel (fig. 19). Wood in the upper loess has been dated at about 28,000 years B.P. The loess and the overlying deposits have been described in detail (White, 1953; Winslow and White, 1953, p. 36-39; White, 1968). The mollusks in the Farmdalian loess have been described by Leonard (1953).

Just at the close of the Farmdalian Substage, lacustrine silt was deposited above the Farmdalian loess in a lake at the Cleveland locality. Wood preserved in the lacustrine silt is dated at about 24,000 years B.P. (White, 1968). The silt contains beetle fragments, which have been described by Coope (1968). The date of the loess at 28,000 years B.P. and of the lacustrine silt at 24,000 years B.P. define the duration of Farmdalian time at Cleveland.

Farmdalian silt of windblown origin occurs upon weathered Millbrook Till in a gravel pit on the south edge of the village of Funk, Plain Township, Wayne County. Similar

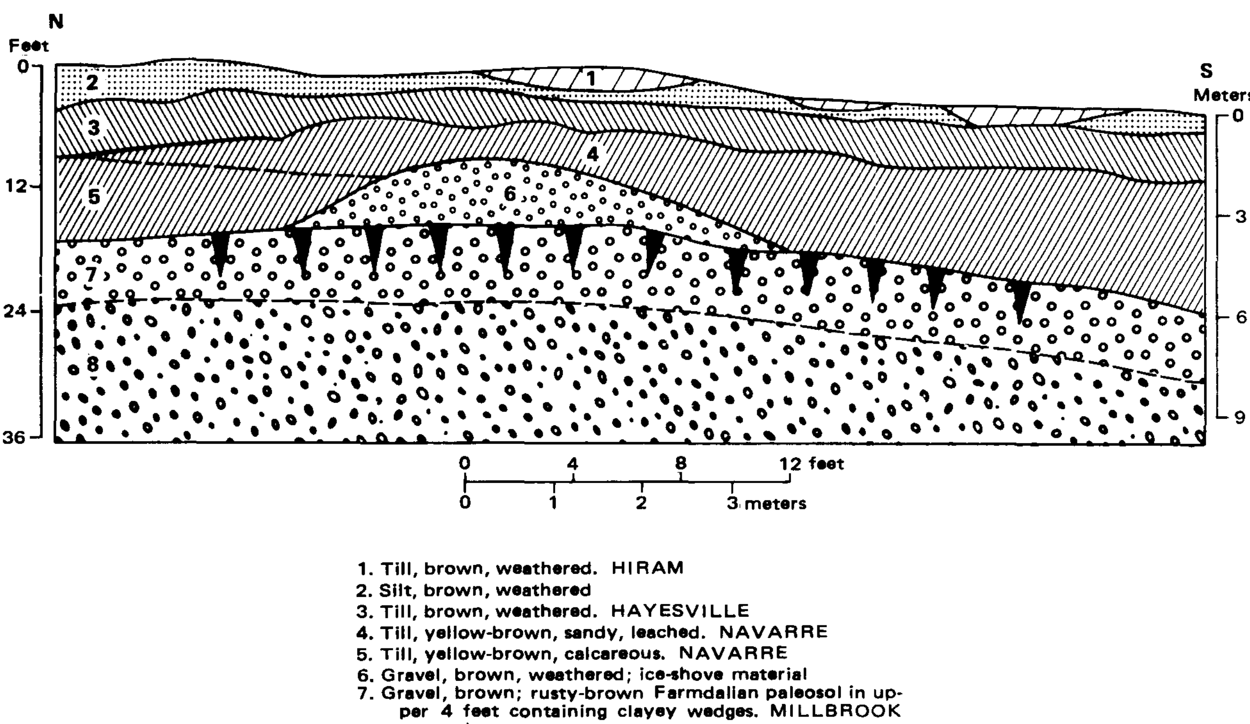


FIGURE 23.—Sketch of glacial deposits exposed along the wall of an inactive gravel pit, NE¼SW¼ sec. 25, Cass Township, Richland County (modified from Totten, 1973, p. 22, fig. 19). Note permafrost wedges in buried Farmdalian paleosol.

silt occurs in the same stratigraphic position 3 miles southwest in NW¼ sec. 39, Mohican Township, Ashland County (White, 1967, p. 35).

During Farmdalian time the Altonian surface suffered some erosion, and at places stream channels were cut into the till. Some channels were filled by alluvial silt, sand, or gravel, or by proglacial outwash as the Woodfordian ice advanced. The channels are most noticeable along deeper excavations of interstate highway cuts (fig. 24). They stand out prominently as apparent lenses of sand or gravel, but are in reality exposures of extensive channels. They are commonly water bearing (Norris and White, 1961, fig. 17.1). The channels have a cover of later till and are not evident at the surface. After the highway cuts are covered with vegetation the channels are evident as wet spots along the slopes; large channels may form springs that require special treatment for slope stabilization. Some channels are large and continuous enough to be mapped away from the cuts by noting a line of productive water wells; these wells may have been affected when deep excavations intersected the buried channel (Norris and White, 1961).

WOODFORDIAN SUBSTAGE

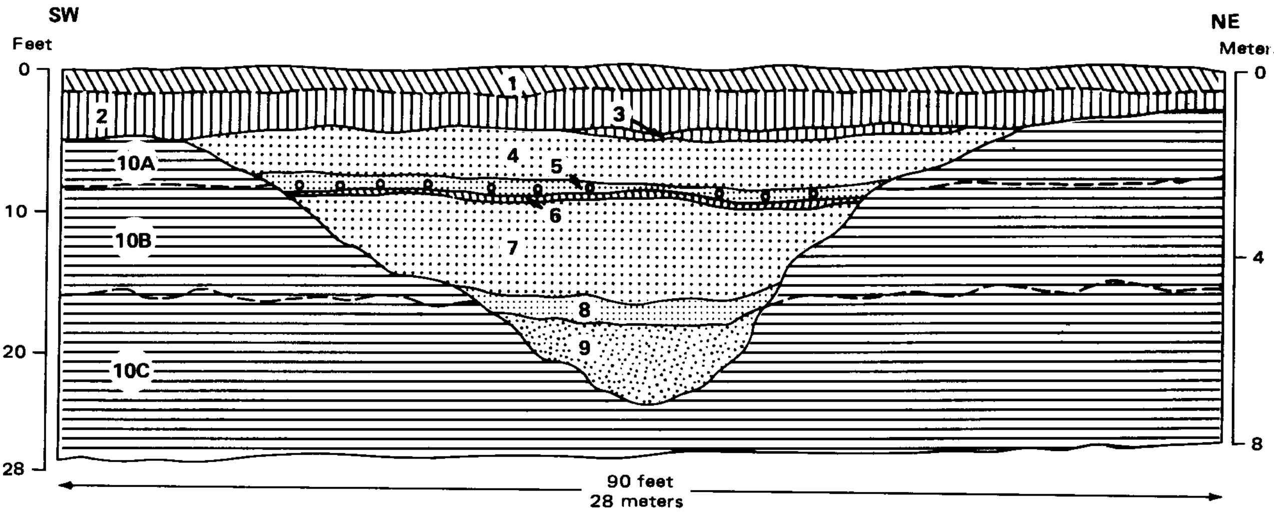
The youngest tills of northeastern Ohio are of Woodfordian (late Wisconsinan) age (table 2). The tills are arranged in a series of overlapping sheets; the earliest Woodfordian till extends farthest south and the later ones end successively farther north (pl. 1; fig. 5). The two earlier Woodfordian tills are correlative in the different lobes, but have been given separate names. The two later Woodfordian tills are continuous across northern Ohio. The Woodfordian tills are generally thin (fig. 14), so that in many outcrops the underlying Altonian till forms the bulk of the drift.

Kent Till

Location and extent.—The Kent Till of the Grand River lobe is named for the type locality near Kent, Portage County (White, 1960, p. 8). It is present at the surface around the periphery of the Grand River lobe in a belt 5 to 10 miles wide in western Geauga, Portage, and Stark Counties and up to 15 miles wide in southwestern Mahoning County and northern Columbiana County. About half of this area has widely scattered thin patches of Lavery Till and is mapped (pl. 1) as "thin Lavery," but more than 95 percent of the surface is Kent Till. The Kent Till is present beneath the later Lavery and Hiram Tills in almost all of the remainder of the Grand River lobe. The Kent Till has a median thickness of 5 feet; it is not continuous and at places is missing. The underlying Titusville drift is at or very close to the surface.

The Kent Till of the Cuyahoga lobe of northern Summit County and Cuyahoga County is entirely a subsurface unit indistinguishable from the Kent Till of the Grand River lobe and will not be described separately. Its margin in northern Summit County is just north of the Lavery margin.

Composition.—The Kent Till is sandy and pebbly to stony, containing more sand than clay, but not quite as much sand as the Titusville Till (table 4). The feldspar



1. Till, very much weathered, and soil. CENTERBURG
2. Till, dark-brown, noncalcareous; yellow and gray mottles. MT. LIBERTY
3. Till, dark-brown (5YR 4/3), calcareous with white limestone spots. MT. LIBERTY
4. Silt, tan to yellow, much-weathered, noncalcareous
5. Silt, pebbly; some cobbles; colluvium
6. Clay, very dark gray, plastic; in prisms, with rust and clay between
7. Silt, noncalcareous
8. Silt, gray to yellow-brown, sandy, laminated, calcareous
9. Sand, light-yellow-brown, silty, hard, massive, calcareous

10A. Till, yellow to olive-brown, sandy, pebbly, leached. JELLOWAY

10B. Till, same as above but calcareous. JELLOWAY

10C. Till, very dark gray (5YR 5/3), sandy, pebbly; 33% sand, 20% clay. JELLOWAY

FIGURE 24.—Sketch of small buried interglacial valley exposed on northwest side of excavation for I-71, SW¼NE¼NW¼ sec. 33, Perry Township, Morrow County, 1⅝ miles northwest of Waterford. Note thin Mt. Liberty and Centerburg Tills; Knox Lake Till not present. Thick Jelloway Till characteristically makes up the bulk of the till section.

content of the few available samples is slightly higher than that of Titusville Till; the quartz content is therefore lower. The till is mealy and not nearly as hard as the Titusville Till.

Weathering character.—Unweathered Kent Till is gray. The oxidized till is yellow brown, in contrast to the underlying olive-brown Titusville Till. In Portage County, from which the most data are recorded (Winslow and White, 1966, fig. 19), the Kent Till is oxidized to depths of 10 feet to 13 feet 6 inches; the average is 10 feet 9 inches. The oxidized till has few or no manganese and rusty stains along joints and around pebbles and is not as compact as the Titusville Till. The Kent Till is leached to a depth of 5 to 6 feet; the average is 5 feet 5 inches.

Stratigraphic position.—The Kent Till in the Grand River lobe is underlain by Titusville Till and gravel. In the small Cuyahoga lobe in the northern half of Summit County and in Cuyahoga County, the Kent Till overlies Mogadore Till and gravel. The Kent Till of the Cuyahoga lobe appears to be less gravelly and quite discontinuous. North of the area where the Kent Till is the surface material, Lavery Till overlies Kent Till.

Age and correlation.—The Kent Till has been traced from its type locality at Kent, Ohio (White, 1960, p. 5), throughout the Grand River and Cuyahoga lobes. It is correlated with the Navarre Till of the Killbuck lobe. The Kent Till has a probable age of about 23,000 years.

Kent outwash

Much Kent material was deposited by meltwater near the edge of wasting ice. Inasmuch as these kame materials were deposited over Titusville gravels, the distinction between the two is not always clear. Generally, however, it can be seen that the Kent gravel is much thinner and more rubbly than the underlying Titusville gravel and not as cleanly washed.

Kent valley trains are represented by the lower terraces in valleys beyond the Kent margin. Particularly good examples are terraces in Sandy Creek valley in Columbiana and Stark Counties and other valleys in Stark County (DeLong and White, 1963, p. 151-153, fig. 63, pl. 2). Other good examples are in the Ohio River valley in Columbiana County, where Kent terraces are the lowest outwash terraces (fig. 8).

Navarre Till

Location and extent.—The Navarre Till of the Killbuck lobe was named for exposures near Navarre, Stark County (White, 1961, p. 72). It is present in western Stark County, in all of Wayne County except for a small area in the northeastern corner, in northern Holmes County, and throughout much of Ashland and Richland Counties. It is concealed beneath the Hayesville Till in much of the area, but crops out beneath the Hayesville in excavations and along stream banks. In places, the overlying Hayesville Till is thin or absent, and the Navarre Till is the surface material, especially in the 5- to 8-mile-wide outer marginal belt of "thin Hayesville" Till (pl. 1). In this belt the Hayesville Till is so thin and discontinuous that the Navarre Till is the surface material over 90 percent or more of the surface.

The Navarre Till is in general a thin till, ranging from 0 to 18 feet in thickness, with an average of 6.9 feet and a median of 6 feet (table 6; fig. 14). It is discontinuous and is missing in at least one-third of the outcrops.

Composition.—The Navarre Till is sandy, very similar in composition to the Kent Till (table 5), and is moderately calcareous. At places the Navarre Till passes into gravel, which is generally more poorly sorted than underlying Millbrook gravel. The more mealy character of the Navarre Till contrasts sharply with the much denser and more compact Millbrook Till.

Weathering character.—Unweathered Navarre Till of horizon 5 is dark gray. The till of horizon 4 is bright yellow brown, in contrast to the olive brown of the corresponding horizon in the Millbrook Till and to the more drab brown of this horizon in the Hayesville Till. The top of horizon 4, the depth of leaching, is generally 5 feet to 5 feet 6 inches below the surface. Horizon 3 resembles horizon 4 except that some staining appears along the joints, and the carbonates are leached.

Where the Navarre Till is at the surface the soils are mainly Wooster and Canfield loams or silt loams. Such areas may be extensive or quite restricted, as in places where the Navarre Till crops out in small areas surrounded by Hayesville Till. This patchy surface outcrop of the Navarre Till is reflected in the various county soil maps, which show isolated areas of Wooster soil interspersed with areas of soils derived from Hayesville Till.

Stratigraphic position.—The Navarre Till overlies the Millbrook Till and the Farmdalian paleosol which is present in some locations. The Hayesville Till overlies the Navarre Till, but as mentioned, the Hayesville Till is at places thin and discontinuous. At a very few places a thin leached zone occurs at the top of the Navarre Till and below calcareous Hayesville Till, but no real soil has so far been observed.

Age and correlation.—The Navarre Till is correlative with the Kent Till of the Grand River lobe and the Knox Lake Till of the Scioto lobe. On the basis of correlation with the Kent Till, the Navarre Till is probably about 23,000 years old.

Knox Lake Till

The Knox Lake Till of the Scioto lobe occupies a very small area in southwestern Richland County. The Navarre Till of the Killbuck lobe has been traced directly into the Knox Lake Till. South of Richland County in western Knox and eastern Morrow Counties the area covered by Knox Lake Till expands. The Knox Lake Till was named (Root, Rodriguez, and Forsyth, 1961, p. 126) for an exposure near Knox Lake, Knox County. Its character in Richland County has been described by Totten (1973, p. 31). As it is so similar to the Navarre Till and occupies such a few square miles in the area of this report, it is not necessary to discuss the Knox Lake Till here. The age is now regarded as Woodfordian, rather than as early Wisconsinan, as proposed by Root, Rodriguez, and Forsyth (1961, p. 137). The Knox Lake Till is not everywhere present at the surface or in the subsurface.

Lavery Till

Location and extent.—The Lavery Till of the Grand River lobe is the surface till in a large area in southeastern Ashtabula, eastern Trumbull, eastern and southern Mahoning, northern Columbiana, northeastern Stark, and central Portage Counties, and a very small area in southern Geauga County (pl. 1). This till is most unusual in that beyond the area of generally continuous Lavery Till there is a peripheral belt 1 to 10 miles wide of extremely discontinuous Lavery Till. Only very widely scattered small thin patches of Lavery Till are present in this belt to indicate the Lavery ice sheet advanced to the limits shown on plate 1. So small and scattered are these peripheral patches that their existence was not realized for many years (White and Totten, 1973). The glaciodynamic mechanism by which these marginal small deposits may have formed has been discussed by Meneley (1973).

The Lavery Till has been traced from its type locality at Lavery, Pennsylvania (Shepps and others, 1959, p. 38), across the Grand River lobe in northwestern Pennsylvania and eastern Ohio. The Lavery Till in northern Summit County and Cuyahoga County is a deposit of the Cuyahoga lobe, but is clearly related to the Lavery Till of the Grand River lobe and will not be considered separately. In the subsurface, below the later Hiram Till, the Lavery Till is almost always present, although its median thickness is only 4 feet (table 6; fig. 14).

Composition.—The Lavery Till is a clayey silty till; in general, it contains about 28 percent sand and 30 percent clay, but the percentages differ from county to county (table 4). The Lavery Till is sparingly pebbly, containing only a few cobbles and boulders, in marked contrast to earlier tills. A high proportion of the pebbles in the Lavery Till are flat angular pieces of shale and siltstone.

The feldspar content of the Lavery Till is higher than that of Titusville and Kent Tills, but is lower than that of the Hiram Till. The feldspar content is about 28 percent and the quartz content about 72 percent (Totten, 1960). The Lavery Till is markedly calcareous.

Weathering character.—Unweathered Lavery Till is dark gray; weathered Lavery Till is dark brown, in contrast to the yellow-brown oxidized Kent Till and olive-brown oxidized Mogadore and Titusville Tills. The depth of leaching of the Lavery Till is generally about 3 feet 6 inches, but ranges from 3 feet to a little more than 4 feet. Just at the base of the leached till a zone of calcite accumulation extends 1 to 3 inches into the top of the calcareous till. The accumulation is greatest along the joints. On the surface of a bank which intersects this zone of concentration the calcite appears as very irregular rather flat small hard white or gray masses which look like small gray pebbles and are sometimes mistaken for shale fragments. Farther back in the bank, the calcite concentrations are soft and almost clayey rather than hard crystalline fragments, as they are at the surface.

After a short time, slopes of fresh-cut banks accumulate pebbles, mainly pieces of shale and siltstone. This accumulation gives the appearance of a very pebbly, almost gravelly material, but actually the proportion of pebbles in the Lavery Till is quite small. The concentration of these pebbles on the slopes is greater for the Lavery Till (and correlative tills of the other lobes) than for the overlying Hiram Till and is one characteristic which distinguishes the two tills.

Soils developed on the Lavery Till are the Rittman silt loam in moderately well drained areas and the Wadsworth silt loam in somewhat poorly drained areas (Ritchie and Steiger, 1974).

Stratigraphic position.—The Lavery Till is underlain by the Kent Till, or where the Kent Till is missing by the Titusville Till. Where the Lavery Till lies directly on Titusville Till a paleosol of Farmdalian age with pieces of siltstone may mark the contact of the two tills. The contrast between the dark-brown Lavery Till and either the yellow-brown Kent Till or the olive-brown Titusville Till is striking. The difference between the clayey silty texture of the Lavery Till and the coarser texture of the underlying till is noticeable.

North of the area of outcrop the Lavery Till is overlain by the clayey Hiram Till or at some localities by a thin layer of sand or silt. In eastern Portage County and western Trumbull County a thicker sand layer has been called the Windham Sand (see p. 46).

In many places the Hiram Till is very thin, in some places so thin that it is incorporated into the present soil; thus the Lavery Till is so close to the surface that the soils are Rittman-Wadsworth rather than Ellsworth-Mahoning, which generally are developed on Hiram Till. The only place in the Grand River lobe where any evidence of erosion or weathering on the Lavery Till below the Hiram Till was seen was at Hudson, Summit County, where an organic zone a few inches thick separates these two tills.

Age and correlation.—The Lavery Till has been traced from its type locality in Pennsylvania (Shepps and others, 1959, p. 38) on the surface and in the subsurface throughout the Grand River and Cuyahoga lobes. It is correlated with the Hayesville Till of the Killbuck lobe (White, 1961) and the Mt. Liberty Till of the Scioto lobe (Totten, 1973, p. 31). Its exact age is not known, but it may be about 19,000 years.

Lavery outwash

Lavery outwash is scanty and inconspicuous. Only the most meager gravel deposits were formed in this age.

Hayesville Till

Location and extent.—The Hayesville Till is named for exposures near Hayesville in southern Ashland County (White, 1961, p. 73). This till is at the surface in a belt 3 to 10 miles wide across western Summit, southeastern Medina, western Stark, almost all of Wayne, northern Holmes, southern Ashland, and central Richland Counties (pl. 1; fig. 5). The Hayesville Till is present north of the area of surface outcrop beneath the later Hiram Till.

The average thickness of the Hayesville Till is 5.2 feet (table 6; fig. 14). In areas where the Hayesville is much thinner than average, the underlying Navarre Till or even the Millbrook Till is the predominant material in outcrops. In an outer belt 5 to 7 miles wide the Hayesville Till is composed of very widely separated small patches of thin till similar to the patchy distribution in the outer margin of the Lavery Till in the Grand River lobe and the Mt. Liberty Till in the Scioto lobe. These patches are so inconspicuous that the Navarre Till is chiefly the surface till, and careful examination is required to demonstrate the presence of Hayesville Till (White and Totten, 1973).

Composition.—The Hayesville Till is silty and clayey. The average sand content ranges from 31 percent in the eastern part of the Killbuck lobe to 25 percent in the western part (table 5). The average clay content ranges from 24 to 29 percent. The silt content is notably uniform (about 45 percent) throughout the lobe. The carbonate content ranges from 4 to 8 percent. The Hayesville Till is only moderately to sparingly pebbly, and cobbles are not common.

Weathering character.—Unweathered Hayesville Till is gray. The oxidized till is chocolate brown, in direct contrast to the yellow-brown Navarre Till and the olive-brown Millbrook Till. The contrast is very evident in outcrops.

The Hayesville Till is leached about 4 feet on the average, but the depth of leaching ranges from 3 feet 6 inches to 4 feet 6 inches. A zone of secondary calcite may be present just below the leached zone. The soils of the Hayesville Till are generally Rittman-Wadsworth on the east, grading into the similar Cardington-Bennington soils on the west.

Stratigraphic position.—The Hayesville Till is underlain by the Navarre Till. The Navarre Till itself is generally thin; at about one-third of the exposures the Navarre is not present, and the Hayesville Till rests upon Millbrook Till. In such places the Hayesville Till may be thick enough to preserve calcareous till at the base. In some places the base of a Farmdalian paleosol may be preserved.

The Hayesville Till is overlain by the Hiram Till north of the surface outcrop of the Hayesville. Because the Hiram Till is thin at many places and very thin at others, the Hayesville Till may be very close to the surface. In most outcrops where 6 feet or more of drift is exposed, the Hayesville Till may be seen.

Age and correlation.—The Hayesville Till is correlated with the Lavery Till of the Cuyahoga and Grand River lobes by direct tracing in northwestern Summit County. It is therefore assumed to have the same age as the Lavery Till. The Hayesville Till also is correlated with the Mt. Liberty Till of the Scioto lobe by direct tracing in southwestern Richland County.

Mt. Liberty Till

Location and extent.—The Mt. Liberty Till of the Scioto lobe is present in the area of this report only in southwestern Richland County (pl. 1; fig. 5). The Mt. Liberty Till was named (as a soil, Root, Rodriguez, and Forsyth, 1961, p. 125) for the village of Mt. Liberty in southwestern Knox County. In Richland County and to the south of the study area the Mt. Liberty Till is continuous; beyond the area of continuous Mt. Liberty Till is an area of patchy cover similar to that of the Hayesville Till of the Killbuck lobe and the Lavery Till of the Grand River lobe. The margin of the Mt. Liberty soil of Root, Rodriguez, and Forsyth (1961, pl. 5) is the margin of the more continuous Mt. Liberty Till. This boundary is also essentially the margin of Wisconsinan till as mapped by White (1937). As much as 12 miles east of this boundary, almost to the margin of the Scioto lobe in Knox and Coshocton Counties, very discontinuous and thin patches of characteristic dark-brown Mt. Liberty Till are present above the yellow-brown Knox Lake Till or, where that is missing, the olive-brown Jelloway Till (White and Totten, 1973). These isolated patches were noted by Root, Rodriguez, and Forsyth (1961, table 13, p. 124), who described them as a "strong brown (7.5YR 5/6) clay-rich (probably due to soil-forming activity) silt cap" on till then believed to be Illinoian, but now known to be early Wisconsinan (Altonian) from direct tracing from the Killbuck lobe. The upper part of this material may be derived from a silt cap, but the bulk of the material contains some pebbles, is calcareous at depths of less than 4 feet, and is therefore till.

Composition.—Totten (1973, p. 31) has described the Mt. Liberty Till in Richland County as

> . . . silty, sandy, and moderately pebbly. Analyses of Mt. Liberty Till samples average 37 percent sand, 42 percent silt, and 21 percent clay, a more sandy composition than that of the Hayesville Till. The average carbonate content is 12 percent, and the average quartz/feldspar ratio is 2.7. The clay mineral composition is 80 percent illite, 5 percent chlorite, and 15 percent kaolinite.

Weathering character.—Totten (1973, p. 31) also has described the weathering characteristics of the Mt. Liberty Till.

> The till is dark brown to yellow brown (10YR 4/3, 4/4, 5/4) where oxidized (horizon 4) and dark gray where unoxidized (horizon 5). Oxidation has reached a depth of about 9 feet and leaching a depth of 38 to 60 inches. Irregular horizontal partings are common in the oxidized till. The soil profile contains some manganese stains and thin clay coatings, but they are not as extensive as in the older Knox Lake Till. A layer of silt about 1 foot thick is generally present capping the till. Alexandria soils are mapped on the moderately steep slopes of the Mt. Liberty Till area in Richland County.

Where the Mt. Liberty Till is thicker than 5 feet, the base is calcareous, in contrast to the underlying till. However, the Mt. Liberty Till is so patchy in the outer belt that the soil in that area is characteristic soil of the underlying Knox Lake and Jelloway Tills.

Stratigraphic position.—Mt. Liberty Till having the appearance of Hayesville Till has been traced west of Richland County beyond the study area. In 1959, when the excavations for I-71 were fresh and clear, the characteristic brown Hayesville Till was very evident at the top of the cuts passing westward into Morrow County as the Mt. Liberty Till of the Scioto lobe (fig. 24). This till was generally only a few feet thick and rested upon Knox Lake Till (Navarre Till in the Killbuck lobe), or, where that till was missing, upon the Jelloway Till (Millbrook Till in the Killbuck lobe). Very thin Centerburg Till (Hiram Till in the Killbuck lobe) was evident above the Mt. Liberty at most places, but at some places the Centerburg Till was so thin it was included in the soil.

Age and correlation.—The Mt. Liberty Till of the Scioto lobe is correlated with the Hayesville Till of the Killbuck lobe by direct tracing (Totten, 1973, p. 31).

Windham Sand

At places in northeastern Ohio, sand or silt lies above the Lavery Till and below the Hiram Till. This layer in Richland County has been described and discussed by Totten (1973, p. 25, fig. 26); he ascribed its origin to "windblown silt and sand" of a "widespread cover-sand formation of an arctic nature during [a] short cold recession." In eastern Portage and western Trumbull Counties the sand is conspicuous (fig. 25) and has been described by Winslow and White (1966, p. 33-34):

> A sheetlike deposit of sand overlies the Lavery Till and underlies the Hiram Till in eastern Nelson, eastern Windham, and eastern Paris Townships, Portage County, and in adjacent Newton and Braceville Townships, Trumbull County. This formation is called the Windham Sand from the township of that name . . . . The Windham Sand is an outwash deposit laid down in an irregular sheet when the Lavery ice was retreating. In the retreat it may have stood for a time along a line extending from east-central Nelson Township to southern Southington and northern Braceville Townships . . . .
>
> The Windham Sand generally overlies the Lavery Till, but at a few places it lies on Kent Till or on bedrock. The Windham Sand is generally overlain by younger Hiram Till whose thickness ranges from as much as 10 feet to a sheet so thin that it is incorporated in the modern soil. At places the Hiram Till is absent, and the Windham Sand forms the surface material . . . .
>
> The Windham Sand ranges in thickness from a few inches to 10 or more feet. In the type section at the sandpit of the Dutter-Miller

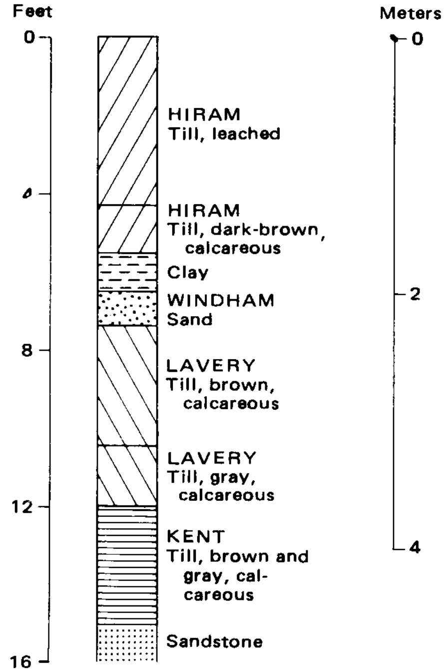


FIGURE 25.—Stratigraphic relation of Windham Sand as shown in excavations for Ohio Turnpike bridge over B & O Railroad, 2 miles east of Newton Falls, Trumbull County (modified from White, 1971b, fig. 4A).

Sand and Gravel Co. in northeastern Windham Township, half a mile south of the Erie Railroad and 1 mile west of the county line, the Windham Sand ranges from 11 to 18 feet in thickness. It lies upon Lavery Till and is overlain by 3½ feet of Hiram Till . . . . The sand probably is much thicker in the buried-valley area in southern Nelson Township, but all the sand penetrated in wells in that area may not be of this age.

The Windham Sand generally is fine grained. It is coarser to the northwest, containing pockets of fine gravel in Nelson Township, and becomes finer to the east where, in Trumbull County, it is a fine-grained silty sand that may be well sorted and may lack silt in the upper part.

The bedding of the Windham Sand ranges from evenly thin bedded (or even laminated in Trumbull County) in the lower part where the sand is thickest, to irregularly crossbedded in the upper part of the formation. At many places the upper few feet are very markedly crossbedded in a manner common to sand dunes.

The Windham Sand is the surface material in parts of Nelson and Windham Townships, in the Eagle Creek drainage basin, and in Paris Township southeast of the West Branch of the Mahoning River . . . . The sand has a few low knolls on its surface, especially in Paris Township; these may be small, low dunes now covered by vegetation. The Windham Sand was deposited as an irregular sheet, in ponds and low areas and on wide flat areas over which melt-water streams shifted rapidly. After deposition ceased, or in dry areas during deposition, wind shifted the upper material, even building low dunes in favorable places. Subsequently the Hiram ice advanced over the sand, covering it with a thin discontinuous sheet of clay-till.

The Windham Sand is penetrated in drilling, but even in the buried valleys where the sand is thickest, the material generally is so fine grained that few wells are developed in it.

Hiram Till

The Hiram Till is the most extensive till in northeastern Ohio. It is the only till that can be traced in surface outcrop across the Grand River, Cuyahoga, and Killbuck lobes. It is the material from which is derived the silty clay loam and clay loam soils of much of the northern part of northeastern Ohio. The original distribution of beech forests in northeastern Ohio was almost precisely controlled by the extent of the Hiram Till (Gordon, 1966). As the Hiram Till extends uninterruptedly across all the lobes of northeastern Ohio, it will not be described by separate lobes as were the earlier tills; variations from place to place, however, will be mentioned where appropriate.

Location and extent.—Hiram Till is present in every county in glaciated northeastern Ohio except Holmes and Columbiana Counties (pl. 1; fig. 5). The Hiram Till is characteristically thin; median thickness is 4 feet in the east and 6 feet in the west (table 6). However, there are wide tracts where the Hiram Till is so thin that it is incorporated into the soil and cannot be positively identified and accurately measured, thus the statistics are skewed toward a higher figure. In Lorain County the Hiram Till is especially thin. In places where the Hiram Till is thin or missing, the soil is derived from the earlier Lavery Till.

Composition.—The Hiram Till is the most clay-rich till of northeastern Ohio. Shepps (1953), in his pioneering laboratory and statistical studies of tills in northeastern Ohio, showed that the clay content was higher in the east and lower in the west. The change in sand content was even more definitively shown to be lower in the east and higher in the west. Later analyses of many hundreds of till samples with a wider areal distribution confirmed this determination (tables 4 and 5). (It should be pointed out that in 1953 the Hiram Till was called late Cary; the Lavery Till, for a time called middle Cary, was not recognized in 1953.)

The Hiram Till is only sparsely pebbly, and boulders and cobbles are rare. In some places pebbles are so inconspicuous that at first sight the material seems almost lacustrine, but closer examination discloses that it does have pebbles and a few cobbles.

The Hiram Till has the highest feldspar content of any of the tills except the later Ashtabula Till. On the east the mean feldspar content is 27 percent (table 3), and on the west mean content is 32 percent (Totten, 1960, p. 18). The Hiram Till is markedly calcareous; the carbonate content reaches 17 percent (Totten, 1973, p. 26) in places.

Weathering character.—Unaltered Hiram Till is dark gray. Oxidized Hiram Till is chocolate brown (technically dark yellowish brown), very similar to the color of the underlying Lavery or Hayesville Till. Where the two oxidized tills are visible in an exposure, the difference in color is subtle but clearly evident. The weathered Hiram Till is more clayey than the Lavery Till. It breaks up into small prisms (peds), which are slightly different in size from those of the Lavery Till. The Hiram Till generally is leached to a little less than 3 feet, but depth of leaching ranges from 2 feet to 3 feet 6 inches.

The soils on the Hiram Till are silt loams. (To the nonexpert these may look like silty clay loams, but are classified by soil scientists as silt loams.) As the silt loams cover such a large part of the area, they are of great importance. Their generally poor drainage is a matter for concern. Silt loams have been studied in great detail in several of the counties in northeastern Ohio. In Ashtabula County these soils are classified as Sheffield and Platea (Reeder and Riemenschneider, 1973); in Summit County (Ritchie and Steiger, 1974) and adjacent counties the soils are classified as the very similar Ellsworth-Mahoning silt loams. Farther west in Richland County the soils on the Hiram Till are classified as Cardington-Bennington because the Hiram Till is so thin that the underlying Hayesville Till influences the soil character (Totten, 1973, p. 28, fig. 7).

Stratigraphic position.—The Hiram Till is underlain by the Lavery Till on the east and by the Hayesville Till on the west. It can be distinguished from the Lavery and Hayesville Tills by its slightly different stronger brown color, its higher clay content, and its shallower depth of leaching. At places the Windham Sand lies between the Hiram and Lavery Tills, as already noted. The Hiram Till is overlain only by the Ashtabula Till in northern Ashtabula and Lake Counties and extreme northeastern Cuyahoga County.

Where the Hiram Till, or the correlative Centerburg Till of the Scioto lobe, overlies Lavery Till or its correlatives in fresh cuts, the fewer number of pebbles in the Hiram becomes evident after a short period of weathering. The pebbles are mainly shale and siltstone fragments.

Age and correlation.—The Hiram Till, the youngest till in Ohio except for the Ashtabula Till, has been traced from southwestern New York (Muller, 1977) across northwestern Pennsylvania (Shepps and others, 1959; White, Totten, and Gross, 1969) and northeastern Ohio to beyond Richland County. It was deposited about 17,000 years B.P. A minimum date for disappearance of the Hiram ice is 14,050 years B.P., which is the date of wood preserved in peat in a kettle hole near Lodi, Medina County. The peat could not have begun to accumulate until after the Hiram ice disappeared (Totten, 1976, p. 514).

Hiram lacustrine deposits

In Mahoning and northern Summit Counties, layered silt from a few inches to 2 feet or more in thickness is at the top of the Hiram Till and grades downward into it. This material seems to have formed on top of the waning ice and was let down upon the underlying till when the ice finally disappeared. Areas where this material occurs can be most readily identified on detailed soil maps of Summit (Ritchie and Steiger, 1974, p. 79-80) and Mahoning (Lessig and others, 1971, p. 83) Counties as areas of Geeburg soils. Similar thin lacustrine clayey silt upon Hiram Till exists in Ashtabula County and no doubt in other counties where its presence has not been recognized. Similar layered clayey silts grading downward into till have been observed over large tracts in Saskatchewan (Moran, 1969, p. 110-112).

Hiram outwash

No gravel deposits of Hiram age have been positively identified. However, the meager sand and gravel in northern Twinsburg, Summit County, at the Summit-Cuyahoga County line, may be partly Hiram outwash. This material is very sandy, is largely composed of shale particles, and is quite different from Kent and Mogadore outwash. Elsewhere in Summit County, the silt in the flat area south of Fairlawn in the western part of Akron and extending south to Barberton may represent deposits of water issuing from the margin of the Hiram ice, which reached a point just north of the Lavery boundary. The silt and fine sand deposits in the long depression extending from Northfield southeast past Hudson and in the linear depression extending southeast across Twinsburg Township and along the eastern margin of Twinsburg Township may represent Hiram-age silty sandy outwash that has a strong component of lacustrine origin.

Centerburg Till

The Centerburg Till, named (Root, Rodriguez, and Forsyth, 1961, p. 123) for the village of Centerburg in southwestern Knox County, is present in Richland County in an area of less than 3 square miles and to the south and west of the area of this report. The Centerburg Till is the Scioto-lobe equivalent of the Hiram Till and can be traced northwestward into the Hiram Till in Morrow County (Totten, 1973, p. 32).

The Centerburg Till in extreme western Richland County was easily traceable in 1959 southwestward into eastern Morrow County in the fresh excavations for I-71. The till was generally 2 feet or less in thickness (fig. 24), but at some places it was as much as 4 feet thick and calcareous. Where the Centerburg Till was very thin it was incorporated into the soil, and its presence could only be confirmed by tracing along the extensive cuts to where it became thick enough for positive identification.

The Centerburg Till is silty, sandy, and slightly pebbly, but appears clayey because the weathered till is very sticky when moist. Analyses of Centerburg Till samples average 34 percent sand, 43 percent silt, and 23 percent clay. The average carbonate content is 18 percent. The Centerburg Till has a higher sand/clay ratio and a higher quartz/feldspar ratio than the equivalent Hiram Till (Totten, 1973, p. 32).

The Centerburg Till is dark brown where oxidized (horizon 4) and tends to break into small prisms and cubes. Unaltered Centerburg Till (horizon 5) was not found in the shallow excavations where the till was exposed. The depth of leaching ranges from 24 to 32 inches, and the soil is correspondingly thin and not strongly developed. A thin silt cap is present on the surface of the till in places (Totten, 1973, p. 33).

The Centerburg Till is underlain by the Mt. Liberty Till. These tills can be distinguished by color, texture, and a thin intervening silt layer. In addition, fresh cutbanks, after a very few days, had a higher concentration of shale fragments on the surface of the Mt. Liberty Till.

Ashtabula Till

The Ashtabula Till is named (White, 1960, p. A-10) for an exposure in a deep road cut near Ashtabula. The Ashtabula Till is the youngest till in Ohio and is present only in the extreme northeastern corner of the state. The earlier tills are deposits of lobes which are actually large sublobes of an Erie lobe, but the Ashtabula Till is a deposit of the Erie lobe itself. It was deposited at a time when ice advanced out of the Erie basin only a few miles to the margin of the Allegheny Plateau.

Location and extent.—The Ashtabula Till is present at the surface in a belt 3 to 4 miles wide in northern Ashtabula County, 1½ to 3 miles wide in Lake County, and less than a mile wide in extreme northeastern Cuyahoga County. It is discontinuously present on the surface of the Lake Plain where the overlying lake deposits are missing. The Ashtabula Till is the uppermost material of the Lake Escarpment moraines.

On the Lake Plain, north of the end moraines, the Ashtabula Till is covered in most places by lacustrine silt and fine sand or by the linear ridges of sand and gravel of the ancient beaches. The cliffs along Lake Erie are composed of Ashtabula Till, capped by thick sand in places.

The Ashtabula Till is quite variable in thickness. At places on the moraines the till is only a few feet thick; at other places it may be 20 feet or more thick. Along the lake bluffs the Ashtabula Till was deposited as a wedge against a pre-existing cliff, so that here the Ashtabula Till is as much as 50 feet thick, but a short distance inland the till becomes much thinner. At many places on the Lake Plain the Ashtabula Till was either not deposited or has been removed by erosion, so that bedrock or an earlier till is now at the surface.

Composition.—The Ashtabula Till is calcareous, silty, clayey, and sparingly to moderately pebbly. Cobbles and boulders are present, but are not at all conspicuous. The Ashtabula Till contains many shale and siltstone fragments, which are particularly evident on weathered slopes. In the lower part of the Ashtabula Till, smeared-out shale fragments and streaks and pods of lacustrine silt and clay are characteristic of the till matrix. This aspect of the till is most evident in the lower parts of the lake bluffs.

The sand content of the Ashtabula Till is more variable than that of the other tills, but is almost everywhere less than 20 percent. The clay content is likewise variable, but is generally about 35 percent. The silt content is almost everywhere more than 50 percent, which distinguishes the Ashtabula Till from all other tills, which have less than 50 percent silt. The texture increases in coarseness to the east, especially in adjacent Pennsylvania (Shepps and others, 1959, p. 45). The clay content is noticeably high in illite (from analyses courtesy of H. D. Glass, Illinois State Geological Survey). The high percentage of illite is due to the very high content of ground-up shale.

Where the Ashtabula Till is quite thick, as along the lake bluffs, the unit consists of sheared slabs of till generally separated by a silt layer a fraction of an inch thick. The separate layers are 3 to 8 feet or more in thickness and are most evident where shore erosion has etched out the interface for several inches (fig. 26). Boulder layers or belts are present at one or more of the interfaces between the sheared layers.

Weathering character.—Unweathered Ashtabula Till is dark gray; the oxidized till is dark brown. The Ashtabula Till resembles the Lavery Till in many aspects, including the presence of shale fragments on weathered slopes. The Ashtabula Till, however, has a higher proportion of these shale fragments and is commonly leached to a greater depth than Lavery Till.

The Ashtabula Till is easily distinguished from the Hiram Till, which is at the surface immediately to the south. The Ashtabula Till is leached from 42 to 72 inches, generally 55 inches or more; the Hiram Till is leached from 24 to 36 inches. The contrast is striking in auger samples southward from Lake Erie; within a fraction of a mile one passes from deeply leached till to shallowly leached till.

Stratigraphic position.—The Ashtabula Till overlies the Hiram Till. A layer of silt or sand may lie between the tills. In places the Hiram Till is thin or missing, and the material directly underneath the Ashtabula Till is the Lavery Till. In such cases these two tills are so similar that distinction between them is difficult.

No later till overlies the Ashtabula Till. Along the crests of the end moraines windblown sand, in places in dunes up to 20 feet high, rests upon the till. On the Lake Plain lacustrine silt and clay overlie the Ashtabula Till in large areas. Along the lake bluff the silt and sand cover may reach 30 feet in thickness, but generally is less than 10 feet.

Age and correlation.—The Ashtabula Till is the youngest till in Ohio and can be correlated with no other till in the state. It has been traced across northwestern Pennsylvania into New York State (Shepps and others, 1959, p. 45, pl. 1). No organic material for carbon-14 dating has been discovered, but on the basis of relative ages, the Ashtabula Till may have been deposited about 15,000 years ago.

LAKES

The deposits and erosional forms of glacial and postglacial Lake Erie are treated in Chapter 5. Not related to glacial Lake Erie are many other lakes and their deposits. Throughout northeastern Ohio, lakes existed at the time of

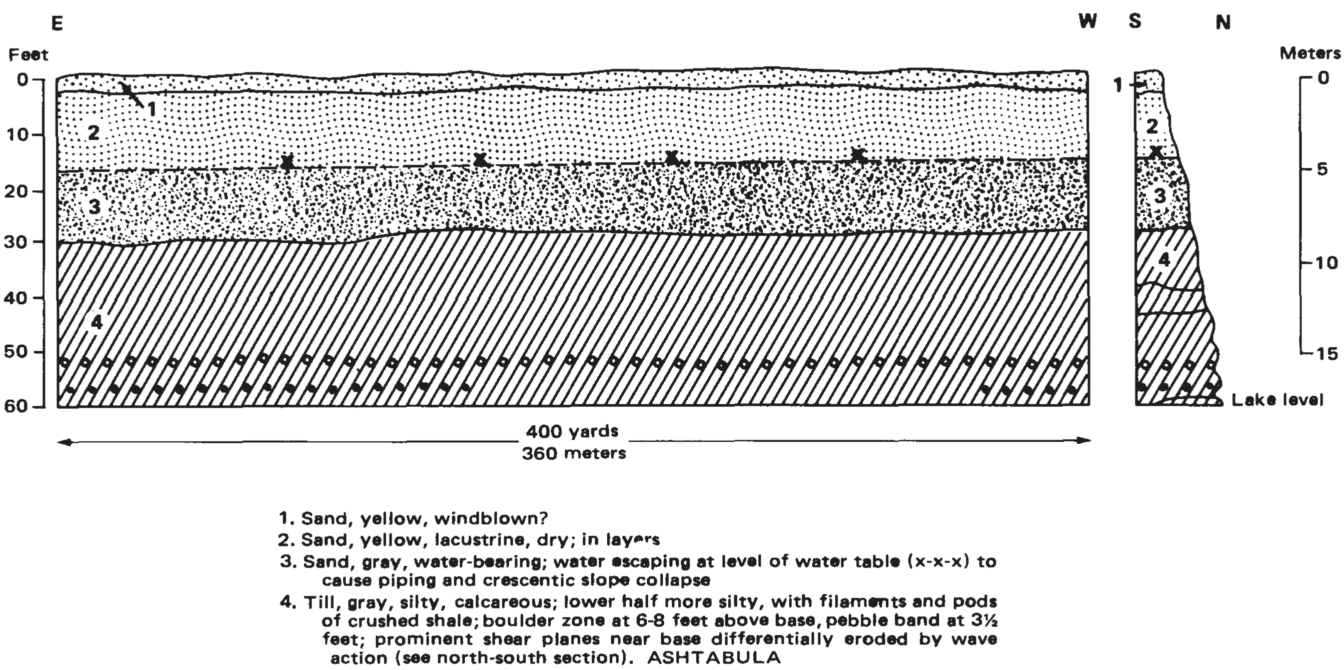


FIGURE 26.—Sketches of lake bluff at Camp Luther, 1 mile west of east line of Kingsville Township, Ashtabula County, showing shear planes in Ashtabula Till and overlying sands and location of piping (from White and Totten, 1979, p. 8, fig. 7).

ice retreat. Some lakes still persist, almost exclusively in kettle holes; the largest of these are the Portage Lakes and Silver Lake in Summit County and Chippewa Lake in Medina County, but many smaller ones are present in every county in northeastern Ohio. Many other lakes, some of large size, existed during the waning stages of the ice and their deposits are important. Only a few of the larger of these are shown on plate 1.

ROCK CREEK AND GRAND RIVER LAKES

The Grand River Lowland in Ashtabula and Trumbull Counties was the site of two lakes at different levels in late Woodfordian time (fig. 27). They have been discussed in detail by White and Totten (1979).

The earlier lake, Rock Creek Lake, at an elevation of 900 to 920 feet, is recorded by thin deposits of silt and clay in northern Trumbull County (White, 1971b) and southern Ashtabula County (White and Totten, 1979). This lake drained eastward across northern Trumbull County to Mosquito Creek and thence southward to the Mahoning River. North of extreme southern Ashtabula County the deposits are exceedingly scanty.

The second, later lake, Grand River Lake, at an elevation of 810 feet, was formed when drainage was established westward from Austinburg, northern Ashtabula County, along the depression between the Painesville and Euclid Moraines. The water flowed into glacial Lake Maumee near Painesville, Lake County, at an elevation of 810 feet. The deposits of Grand River Lake are as much as 200 feet thick. They extend from Farmington, Trumbull County, to Austinburg (pl. 1), a distance of about 30 miles. The deposits are interbedded silty clay, silt, fine sand, and till, recording the existence of a lake not only in late Woodfordian time, but also at various earlier times.

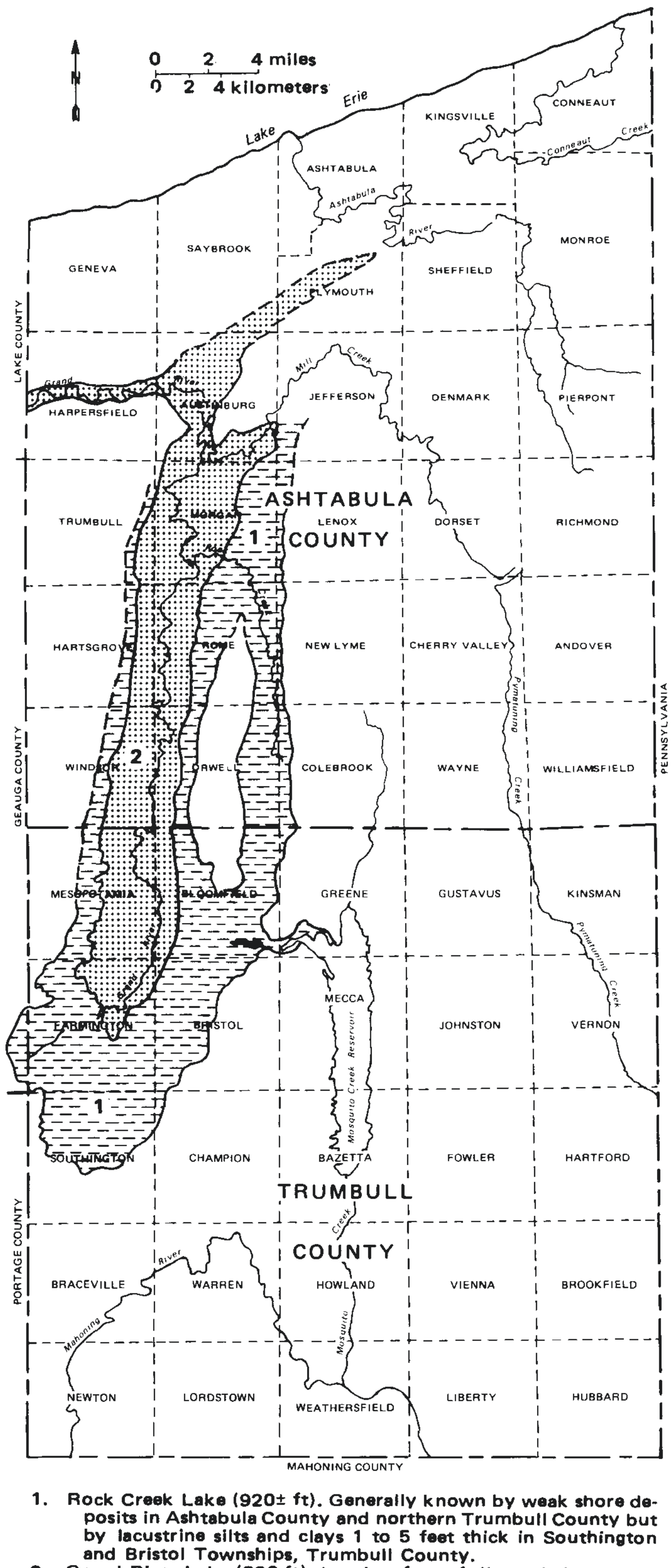
The present surface of the Grand River Lake deposit is a flat plain 1 to 3 miles wide, through which the Grand River flows in a meandering course to Austinburg. A sluggish arm of Grand River Lake extended west from Austinburg; silt, sand, and gravel were deposited in this arm. As lake levels of the predecessors of Lake Erie dropped, the Grand River cut down, leaving deposits at 810 feet as terraces along the present gorgelike valley. A series of knickpoints (sharp changes in gradient) retreated upstream and have now extended a short distance south of Austinburg.

When Grand River Lake was in existence, streams entered the lake from both east and west and deposited deltas and alluvial fans; this material ranges from sand to gravel. In pre-Woodfordian lakes similar materials were deposited, but are now concealed by later lacustrine silts. These buried coarse deposits are present-day sources of ground water (White and Totten, 1979, p. 44).

LAKE SHELBY

Ancient Lake Shelby was described by Hubbard and Rockwood (1942, p. 242-243) as a 9-square-mile tract in northwestern Richland County. Totten (1973) later determined that the lake occupied a much larger area in northwestern Richland and eastern Crawford Counties (pl. 1). According to Totten (1973, p. 42-43, pl. 1) this lake extended

... to the St. Johns Moraine on the north and west and nearly to the Broadway Moraine on the east and south.



1. Rock Creek Lake (920± ft). Generally known by weak shore deposits in Ashtabula County and northern Trumbull County but by lacustrine silts and clays 1 to 5 feet thick in Southington and Bristol Townships, Trumbull County.
2. Grand River Lake (820 ft). Level surface of silts and clays.

FIGURE 27.—Map of Rock Creek and Grand River Lakes in Ashtabula and Trumbull Counties. Boundaries are dashed where approximate; arrow indicates drainage of Rock Creek Lake.

In the northwestern portion of the county the regional slope is toward the north, and no deeply cut valley flowing southward exists. This water was impounded between Hiram-Centerburg ice and the divide, forming a temporary ice-marginal lake. As the ice retreated, lower outlets, probably toward the southwest, were uncovered, and the lake level continued to drop. The level of the final stage, which may have lasted for a time after [Richland County] became ice free, was determined by the lowest level of the basin, at around 1,085 feet, near Ganges. Water poured over this outlet, and a "gorge" was cut down to an elevation of 1,030 feet or lower west and north of Ganges, leading to the demise of the lake. It was during this time that the present anomalous-appearing Black Fork drainage was coordinated. The surface of the lake plain is nearly featureless, except for many small shallow kettles that dot the plain and for several narrow Mississinewa end moraine segments or "islands." The flat plain has poor natural drainage, but dredging and tiling have turned this lake plain into highly productive crop land.

LOESSIAL SILT

In addition to the few examples of loess of Farmdalian age already described, a silt cap is present at the surface in considerable areas of northeastern Ohio. On the map of Pleistocene eolian deposits of the United States (National Research Council, 1952) no eolian deposits are shown on the glaciated Allegheny Plateau in northeastern Ohio. South of the glacial boundary "Wisconsin Loess" is shown as "less than 4 feet thick, less than 33 percent of land covered." At the time that map was compiled it was not realized that a silt cap also is present north of the glacial boundary at many places.

The silt cap may be as thick as 2 feet, but is generally thinner and is incorporated in the present soil. The silt seems to be thicker on the Kent and Navarre Tills, but is present on the Lavery and Hayesville Tills and the Hiram Till. The silt cap is most evident in fresh, smooth highway cuts, where it can be followed for scores or hundreds of feet, and where the variable thickness is evident. There seems to be no increase in any particular direction, as there is in the region adjacent to the Mississippi and Illinois Rivers, where the windblown silt (loess) rapidly decreases in thickness east of these rivers.

Chapter 5

PLEISTOCENE BEACHES AND STRANDLINES BORDERING LAKE ERIE

by

Stanley M. Totten

INTRODUCTION

A strip of land 2 to 12 miles wide bordering Lake Erie in northeastern Ohio was greatly affected by wave action, longshore currents, and wind when lake levels in the Erie basin were considerably higher than the present 571-foot surface elevation of Lake Erie. During each of the interglacial and interstadial (warm) periods, when ice retreated north of Ohio, lakes existed as they have in the time since the last ice left. In the early stages of each series of lakes, water was enclosed between higher land elevations to the south and the thick ice sheet to the north. At lower levels the water occupied only the Erie basin itself, just as does present Lake Erie.

For the most part, in the earlier episodes prior to the most recent (Woodfordian) ice advance the major activity was wave erosion, forming cliffs and terraces as the modern lake is now doing. At the various lake levels following the Woodfordian glaciation, the major activity was the deposition of beach and dune ridges, rather than cliff and terrace cutting. The strandlines are represented on plate 1 by the beach ridges, which have a linear northeast-southwest trend across northeastern Ohio parallel to and near the present shoreline. The cliffs, which closely parallel the beach ridges, are not shown on plate 1, but are shown on maps of the more detailed reports of the lakeshore counties (see p. 5). Only a summary of the rather complex details of these Pleistocene strandlines is given below.

WAVE-CUT CLIFFS AND TERRACES

The wave-cut cliffs and terraces are the most prominent strandline features along the narrow belt of Lake Plain (pl. 1) south of Lake Erie. Whittlesey (1850) and Leverett (1902, 1931) recognized the cliffs and terraces as wave-cut features separate from and predating the beach ridges. Neither geologist developed this idea to any extent, and more recent studies (Carney, 1910, 1911, 1916; Schooler, 1974) make little or no distinction between cliff and terrace cutting and beach-ridge formation. Phillips (1977) demonstrated for Lake Superior that the cliffs and terraces predate the beach deposits there, just as is the case for Lake Erie.

The terraces slope gently toward the lake, and the different terrace levels are separated by steep slopes or cliffs. The line of intersection of the slope of a terrace and that of a cliff, as seen in profile (figs. 29, 30) represents the strandline for that particular wave-cutting episode. The cliffs and terraces were cut into till of Altonian age and have been covered with a thin veneer of till of Woodfordian age, so that the actual lake levels responsible for the strandlines were 5 to 10 feet lower than indicated by surface elevations. The terraces were changed very little by the subsequent Woodfordian ice advance, and little postglacial dissection of the terrace surfaces by running water has occurred.

Three prominent wave-cut cliffs (or sets of cliffs) and terraces are present south of Lake Erie, and on each terrace are two to six beach ridges. The most prominent beach ridges recognized south of the lake (Forsyth, 1959), from highest to lowest, are: Maumee I, II, III, Whittlesey, Arkona I, II, III, Warren I, II, III, Wayne, Grassmere, and Lundy. The wave-cut strandlines do not occur at exactly the same elevations as the beach ridges. However, the Maumee, Whittlesey, and Warren beach ridges occur at the top of prominent cliffs; consequently the cliff and overlying ridge share a common frontal slope and hitherto have been considered a single feature. The cliff and terrace features have long been identified with the associated beaches. However, these erosional forms are earlier than the beaches which are in front or upon them. Therefore, the cliffs and terraces are given separate designations of Upper, Middle, and Lower, with the former names of Maumee, Whittlesey, and Warren in parentheses.

The present cliff of Lake Erie and its bench form a model for the much earlier features. If the Lake Erie water level fell, the present cliff, which would soon assume a stable slope, and the bench, now under water, would form an almost exact analog of the higher cliffs and terraces.

UPPER (MAUMEE) CLIFFS AND TERRACES

Three distinct levels of cliff-terrace development, referred to as Upper (Maumee) Stage I, II, and III, are traceable across northeastern Ohio at elevations of 790, 775, and 755 feet respectively (fig. 31). In Lorain County and western Cuyahoga County west of Cleveland, where the topographic relief is low, the Upper Terraces are well developed and the cliffs generally are low and indistinct. The highest level, Upper I, is represented by a terrace between the Maumee I beach ridge and the 790-foot contour (fig. 28). No distinct cliff is present above the 790-foot contour, only a steeper slope. The middle of the three levels, Upper II, is not a prominent feature, and the cliff is masked by a Maumee beach ridge. The lowest level, Upper III, at an elevation of 755 feet, is represented by a well-developed cliff

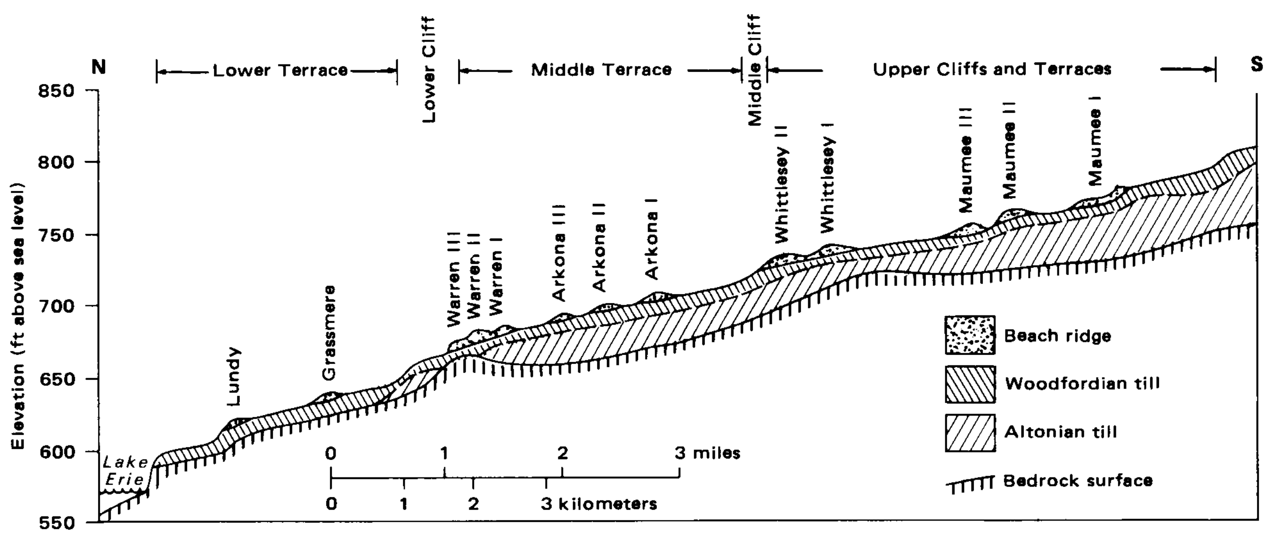


FIGURE 28.–Composite cross section of strandlines south of Lake Erie in Lorain and western Cuyahoga Counties. Three features are evident (1) cliffs and terraces cut into bedrock; (2) cliffs and terraces cut into Altonian till and later mantled with Woodfordian till; and (3) beach ridges on terraces.

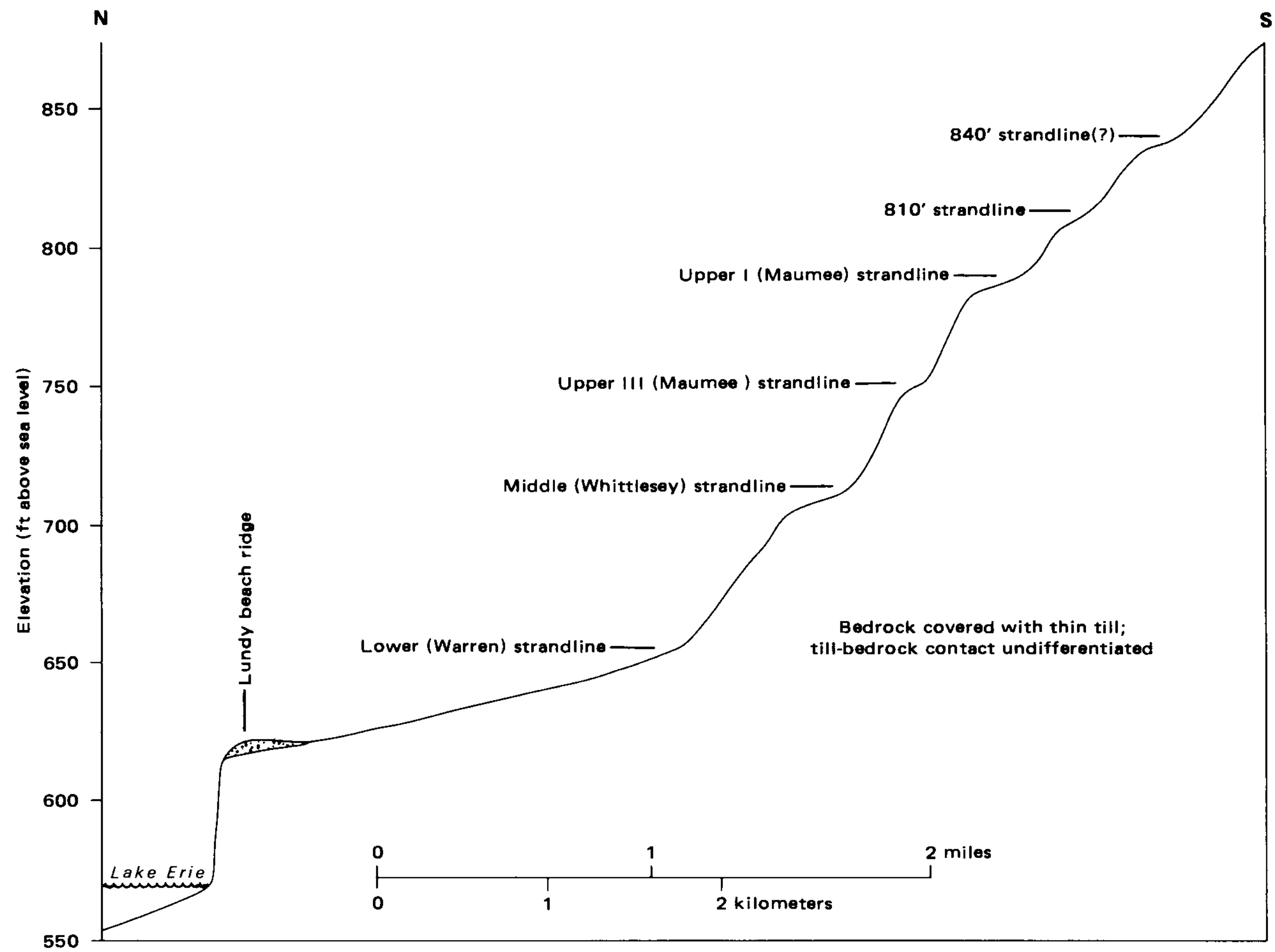


FIGURE 29.–Composite profile of strandlines south of Lake Erie in eastern Cuyahoga County showing cliffs and terraces cut mainly into bedrock. Note absence of beach ridges with the exception of Lundy.

and terrace. The cliff, 10 to 15 feet high, forms the steep frontal (northern) slope of Butternut Ridge. A thin covering of Maumee beach sand is spread over the cliff. The terrace associated with this cliff attains a maximum width of about 3 miles and is poorly drained except for the Maumee III and Whittlesey beach ridges developed on it.

In eastern Cuyahoga County the Euclid Moraine and the Escarpment have combined to produce elevations exceeding 800 feet within 2 miles of Lake Erie, and the strandline appears as a cliff or series of cliffs, up to 160 feet high, broken in places by narrow terraces. Above the Upper strandlines, an additional strandline occurs at an elevation of 810 feet and extends eastward into Lake County. The 810-foot strandline may represent a smaller localized lake episode or it may correlate with a high terrace at an elevation of 860 feet near Erie, Pennsylvania. In a few places in eastern Cuyahoga County yet another terracelike feature of undetermined significance is present at an elevation of about 840 feet (fig. 29).

In Lake and Ashtabula Counties (fig. 30), the Upper strandlines generally are notches cut into the steep frontal (northern) slopes of the Ashtabula, Painesville, and Euclid Moraines. The terraces tend to be very narrow and commonly are absent. The major topographic expression is a cliff that may reach a height of 60 to 80 feet, especially where the Upper and the Middle Cliffs are combined. The Upper III Terrace attains a maximum width of about 2,000 feet in western Ashtabula and eastern Lake Counties, and is overlain by the Maumee III beach ridge and by the Whittlesey beach-dune ridge. Similarly, the Upper II terrace widens to 1,000 feet and is overlain by the Maumee II beach ridge. The Upper II strandline terminates at Kingsville, Ashtabula County. The Upper I strandline cannot be traced farther east than the western part of Ashtabula County. Ashtabula County may represent the eastern margin of Upper I and II lakes when terracing occurred. The Upper III strandline is the highest and earliest that can be traced eastward into Pennsylvania.

The Upper strandline elevations rise northeastward due to glacio-isostatic rebound (fig. 31). The hingeline marking the beginning of rise for the Upper strandlines is located in western Cuyahoga County between Cleveland and Lorain. The amount of tilting increases northeastward, being greatest in Ashtabula County, where the Upper I strandline attains an elevation of 810 feet.

MIDDLE (WHITTLESEY) CLIFF AND TERRACE

The Middle (Whittlesey) strandline consists of a prominent cliff and terrace that formed during a major stillstand of lake level at an elevation of 715 feet. The Middle Cliff is the single most imposing strandline feature in Lake and Ashtabula Counties. Generally the cliff rises 20 to 30 feet above the terrace, but in places where it has cut into end moraines cliff height may reach 50 or more feet. Between the Middle Cliff and the Lake Erie shoreline, all traces of the Ashtabula, Painesville, and Euclid Moraines have been removed by wave erosion.

From Conneaut Creek in Ashtabula County to the Ohio-Pennsylvania state line, a distance of 6 miles, the

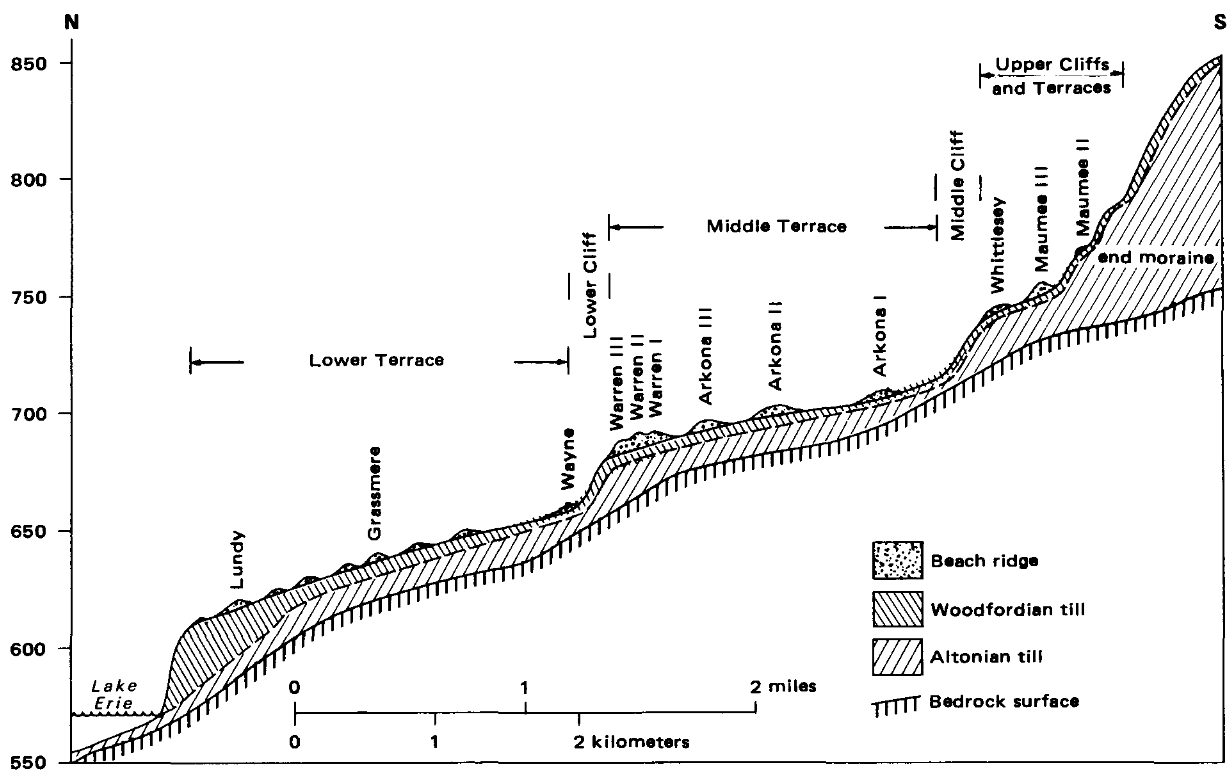


FIGURE 30.–Composite cross section of strandlines south of Lake Erie in Lake and Ashtabula Counties. Three features are evident: (1) cliffs and terraces cut into bedrock; (2) cliffs and terraces cut into Altonian till and later mantled with Woodfordian till; and (3) beach ridges on terraces.

Middle and Upper Cliffs are joined against the steep northern slope of the Ashtabula Moraine to form a steep cliff that towers 50 feet or more above Under Ridge Road at its base. The combined cliffs are 50 to 80 feet high against the northern slope of the Painesville Moraine in Lake County. The Middle Cliff maintains its prominence westward across Cuyahoga County, but is reduced in height to about 30 feet, and to 10 feet in Lorain County. The base of the Middle Cliff rises northeastward from an elevation of 715 feet in eastern Cuyahoga County to an elevation of 725 feet at the Ohio-Pennsylvania state line as a result of glacio-isostatic uplift.

The Middle Terrace north of its cliff ranges in width from nearly 0 in eastern Cuyahoga County to 2.2 miles in Ashtabula County and 4.5 miles in eastern Lorain County. The broad gentle terrace slope provided optimum conditions for beach-ridge formation during a later episode, and several beach ridges–Arkona I, II, and III and Warren I, II, and III–occur on its surface.

LOWER (WARREN) CLIFFS AND TERRACES

The Lower (Warren) strandline consists of two closely related sets of cliffs and terraces north of the Warren beach ridges. The Lower I Cliff, with a base elevation of 660 feet, forms the moderately steep northward-facing slope of North Ridge. The cliff or slope is only 10 to 20 feet high in Ashtabula and Lorain Counties, but is 30 to 45 feet high across much of Cuyahoga and Lake Counties. A second cliff, Lower II, has a base elevation of 650 feet and occurs a very short distance north of Lower I. The Lower II Cliff, which is about 10 feet high, commonly is joined with the Lower I Cliff to form a more or less continuous feature. The Lower strandlines gradually rise about 10 feet in elevation due to glacio-isostatic rebound as they are traced eastward to the Ohio-Pennsylvania state line (fig. 31).

The Lower Terrace north of its cliff ranges in width from 0.3 mile in Cleveland to a maximum of 4 miles in Lorain and Ashtabula Counties. At its widest part the slope of the terrace is about 10 feet per mile, and the low gradient combined with the low permeability of the subsoil have produced swampy conditions in many places. Several low sandy segments of beach ridges, including the more continuous Grassmere and Lundy ridges, occur on the Lower Terrace.

CLIFFS AND TERRACES BELOW THE LOWER (WARREN) TERRACE

The Lower (Warren) Terrace is the lowest erosional level that is clearly evident at the surface in northeastern Ohio, but sketchy evidence exists for still lower erosion surfaces. A cliff about 5 feet high with a base at 615 feet occurs in Lorain County (Totten, unpublished manuscript) near the modern Lake Erie shoreline, and a low terrace with an elevation of about 610 feet in Ashtabula County has been described by White and Totten (1979). In addition, a thick wedge-shaped mass of Ashtabula Till has been plastered against the face of one or more cliffs at low elevations near the present Lake Erie shoreline in Ashtabula County, burying the cliffs in the process. Other cliffs and terraces at lower elevations may have been destroyed by modern lake

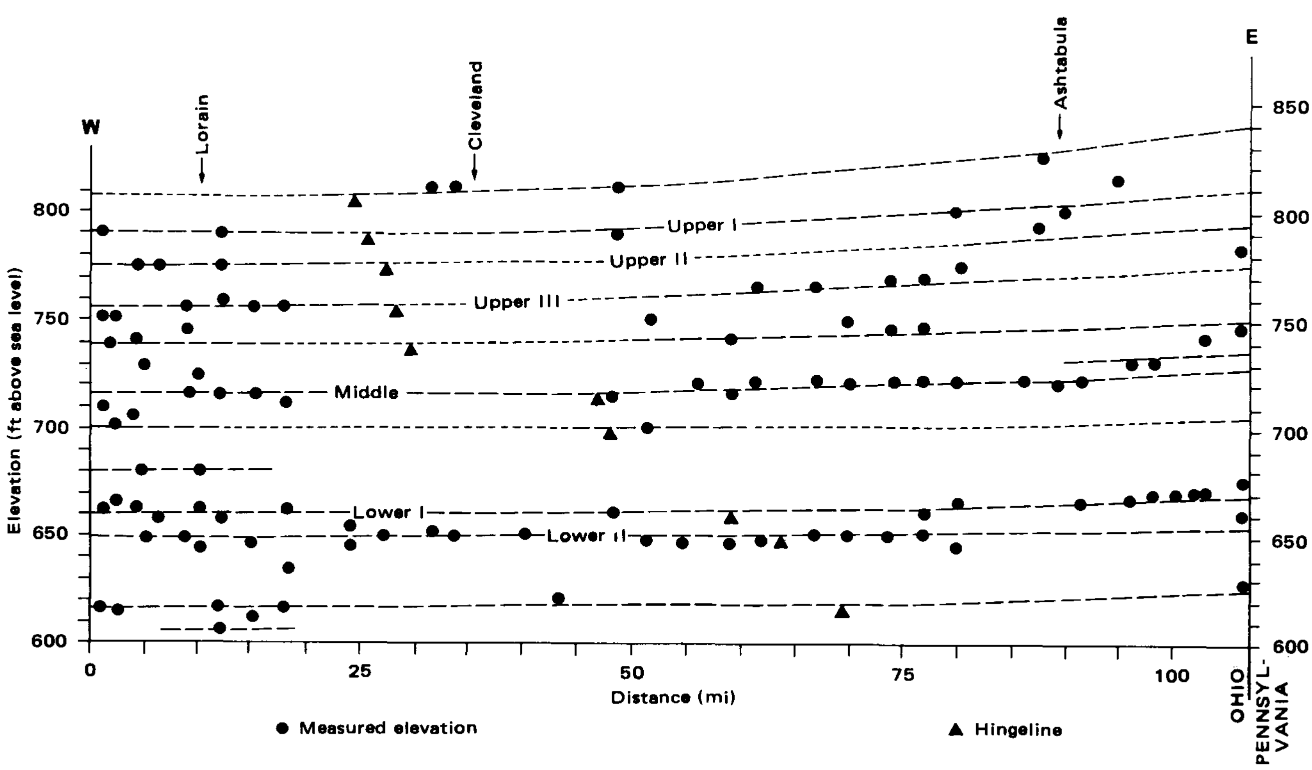


FIGURE 31.–Elevations of intersections of cliffs and terraces in northeastern Ohio. Long-dashed lines represent good correlations, short-dashed lines are projections over greater distances where data are lacking.

erosion of the lake bluffs during the past few hundred to few thousand years.

DATING OF CLIFFS AND TERRACES

The cliffs and terraces were eroded during an ice-free interval in northeastern Ohio when water levels were higher than present. The thickness of till of Woodfordian age is unaffected by the strandlines, proving that this erosional episode preceded the Woodfordian glaciation. The strandlines are younger than the Ashtabula, Painesville, and Euclid Moraines as evidenced by the truncation of the moraines at the Middle (Whittlesey) Cliff and complete removal of the moraines from the Lake Plain. The moraines are composed predominantly of Titusville Till as mentioned in another part of this report. Thus the cliffs and terraces formed after the disappearance of Titusville (Millbrook-Mogadore) ice about 35,000 years ago and prior to the advance of the Kent (Navarre) glacier about 23,000 years ago. The warmest portion of this ice-free period is known as the Farmdalian Substage in the Midwest and as the Plum Point Interstadial in the northeastern Great Lakes region. Other evidence supporting a pre-Woodfordian age for the wave-cut cliffs and terraces includes:

1. Beach ridges occur on terraces, and thus postdate them.
2. The immediate postglacial period was characterized by deposition of beach ridges, not by erosion.
3. Postglacial lake levels fell to below present-day levels in 1,800 years (14,500 B.P.-12,700 B.P.), much too short a period for extensive wave erosion.
4. The wave-cut terraces would require approximately 10,000 years to form based on present erosion rates.
5. Strandline elevations of beach ridges and cliffs-terraces exhibit different rates of isostatic uplift.
6. The valleys of north-flowing streams contain very wide cut terraces that correlate with elevations of wave-cut strandlines. The terraces of at least two valleys, Black River and Rocky River, are mantled by till of Woodfordian age.
7. The thickness of Hiram Till in Lorain County is similar on the Lake Plain and on the till plain to the south, indicating that wave erosion did not occur after the last glaciation.

All the wave-cut strandlines in northeastern Ohio exhibit about the same amount of glacio-isostatic rebound (fig. 31). This similarity in tilting indicates that a substantial, relatively stable ice mass remained in the northeastern Erie basin during the period of shoreline erosion.

STRANDLINES CUT INTO BEDROCK

The bedrock surface buried beneath till and the surficial strandlines was reconstructed from well records for Ashtabula County (White and Totten, 1979). Profiles of the bedrock surface show a series of steps (fig. 30) which are believed to represent wave-cut cliffs and terraces cut at strandline elevations of 740, 690, 635, and 550 feet. Farther west in Lorain County, outliers of Berea Sandstone display nearly vertical cliffs and broad terraces partly buried beneath till (Totten, unpublished Lorain County manuscript). These partly buried strandline features in Lorain County and the buried strandlines in Ashtabula County probably represent pre-Wisconsinan erosion of an early predecessor of Lake Erie. The occurrence of thin Keefus Till (early Wisconsinan(?)) upon the bedrock terraces in northwestern Ashtabula and northeastern Lake Counties suggests the lake around which these strandlines formed dates at least as far back as the Sangamonian Stage.

BEACH RIDGES

The sand and gravel ridges on the terraces already described are conspicuous features on the otherwise flat

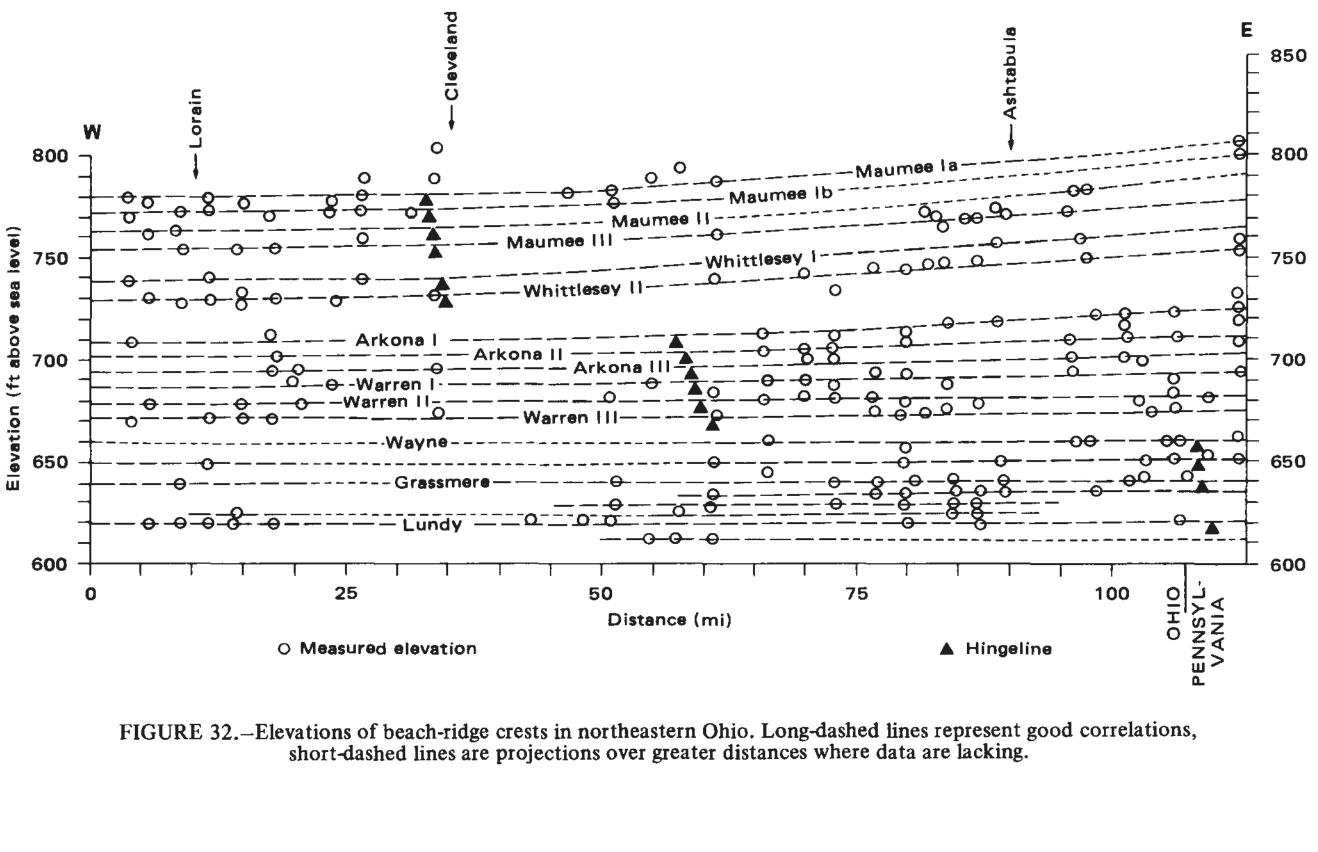


FIGURE 32.–Elevations of beach-ridge crests in northeastern Ohio. Long-dashed lines represent good correlations, short-dashed lines are projections over greater distances where data are lacking.

Lake Plain. These ridges record shorelines of a series of late-glacial and postglacial lakes which stood at higher levels than present Lake Erie.

Following the retreat of Late Woodfordian ice from northern Ohio between 14,000 and 15,000 years ago, a series of lakes at high levels formed that were direct ancestors of present Lake Erie. These lakes were considerably more extensive than present Lake Erie and existed in the depression between the northward-sloping surface of northern Ohio and the final wasting ice masses in the Erie basin, which blocked drainage northward and eastward. These late-glacial lakes, each lasting from about 50 to 300 or more years, left their record on the Ohio landscape mainly in the form of beach and sand-dune ridges (pl. 1).

These beach-dune ridges figured prominently in the settlement of northeastern Ohio because the sandy, slightly elevated ground provided well-drained, nearly level transportation routes and homesites. Somewhat later, the beach ridges gained importance as a source of sand and gravel aggregate for the construction industry.

The beach ridges interrupt the low but continuous northward slope of the terraces, thereby ponding the natural northward drainage. Swamps, many now artificially drained, are common along the southern margin of the ridges, and the smaller drainage lines tend to parallel the beach ridges. The beach ridges, like the cliffs and terraces, rise in elevation northeastward owing to glacio-isostatic uplift (figs. 32, 33).

MAUMEE BEACH RIDGES

The Ashtabula glacier, the last of the continental ice sheets to advance as far south as Ohio, advanced into northeastern Ohio about 15,000 years ago and extended as far southwest as Cleveland, covering eastern Cuyahoga, northern Lake, and northern Ashtabula Counties. The Erie basin west of Cleveland was not covered by the Ashtabula ice advance. The Ashtabula ice sheet blocked northward and eastward drainage in the Erie basin north of Ohio, and a large lake known as Lake Maumee gradually formed between the ice and higher land to the south of the present shoreline of Lake Erie. The highest lake-level elevation, 780 feet, was reached about 14,500 years ago, probably during the retreat phase of the Ashtabula glacier. Forsyth (1959) has reported an earlier beach, which she identified as Maumee I, at an elevation of 800 feet. This earlier beach, which Forsyth (1959) indicated is present only in western Ohio, predates the Ashtabula ice advance and cannot be related to the succession of beaches that began with Maumee I at an elevation of 780 feet about 14,500 years ago.

The three major Maumee beach ridges are termed, from earliest to latest, I, II, and III. In Lorain County the Maumee I ridge has a crest elevation of 780 feet, with a secondary crest in places at an elevation of 774 feet (the crest elevation is 5 to 10 feet higher than the actual lake level when the ridge formed). Maumee II has a crest elevation of 764 feet, and Maumee III has a crest elevation of 753 feet (fig. 32).

The Maumee beach ridges typically are no more than 5 to 10 feet high and 500 to 1,500 feet wide. The Maumee I ridge, known as Butternut Ridge in eastern Lorain and western Cuyahoga Counties, can be traced as far east as Lake County, where Lake Maumee presumably terminated against the retreating ice sheet. The Maumee II ridge is poorly developed because the 764-foot crest elevation is near the top of the Upper III (Maumee) Cliff, a poor place for beach development. The Maumee II ridge can be traced eastward nearly to the Ohio-Pennsylvania state line, which approximates the eastern boundary of Lake Maumee II. The Maumee III ridge is nearly continuous in eastern Lorain and western Cuyahoga Counties, where it is known as Chestnut Ridge. Farther east in Lake and Ashtabula Counties, the

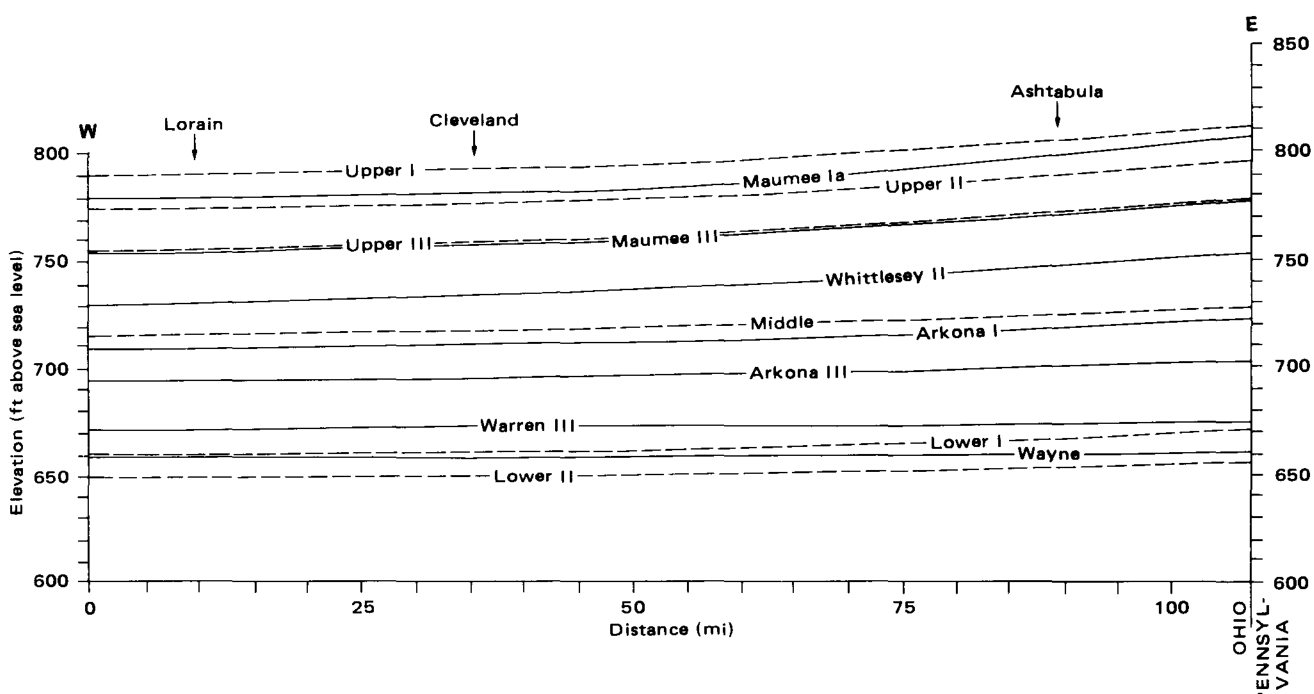


FIGURE 33.–Comparison of elevations of beach-ridge crests (solid lines) and cliff-terrace intersections (dashed lines).

ridge is discontinuous and has been extensively dissected by streams flowing northward down the frontal slope of the Ashtabula and Painesville Moraines. At Kingsville, Ashtabula County, Conneaut Creek formed a delta, and delta sediments were incorporated to form ridges 15 feet or more high. A swimming pool excavation 7 feet deep, cut into one broad ridge segment at the south edge of Kingsville, exposed coarse sand and fine gravel consisting of flat siltstone and rounded crystalline cobbles arranged as beach shingle. The Maumee ridges rise in elevation about 30 feet from Cleveland eastward to Ashtabula County owing to glacio-isostatic uplift following ice retreat. Uplift was occurring while the ridges were forming (and as the glacier was retreating) as evidenced by the greater tilt of the ridges formed at higher elevations as compared with those formed at lower elevations (fig. 32).

WHITTLESEY BEACH RIDGES

The Whittlesey II beach ridge has a crest elevation of about 730 feet and generally has been regarded as the most prominent beach in northern Ohio (Forsyth, 1959, p. 6). Much of its prominence actually is due to its position at the brow of the prominent Middle (Whittlesey) Cliff. The Whittlesey beach, known as Center Ridge in eastern Lorain and western Cuyahoga Counties, where it is followed by U.S. Route 20, is a ridge 5 to 10 feet high and 300 to 800 feet wide. In Lake and Ashtabula Counties the Whittlesey beach is known as South Ridge and is traversed by Ohio Route 84; it can be traced as a continuous ridge, 500 to 1,000 feet wide and about 10 feet high, for 25 miles from Painesville northeastward to Ashtabula. The ridge is covered by dunes in many places, and the continuity of the ridge is broken by small streams that head in the moraines south of the ridge. Large quantities of sand and gravel are associated with the Ashtabula River delta near Ashtabula, and Whittlesey gravel bars connect several islands of the Ashtabula Moraine, which had been isolated from the main morainic ridge by wave erosion at an earlier time. Commercial quantities of sand and gravel have been obtained from this ridge in Ashtabula County.

A second Whittlesey beach ridge, Whittlesey I, with a crest elevation of about 740 feet, occurs a short distance south of the main ridge in widely scattered areas in northeastern Ohio. This poorly developed early Whittlesey ridge is most continuous across Mentor and Painesville Townships in Lake County (White, 1980).

Whittlesey beach-ridge crests rise gradually about 20 feet in elevation owing to glacio-isostatic uplift as they are traced northeastward from Cuyahoga County to the Ohio-Pennsylvania state line.

ARKONA BEACH RIDGES

Lake Arkona was initiated when ice of the Huron-Erie lobe retreated northward and opened a drainage route through the Grand River (of Michigan) channel (Hough, 1958). The Grand River (of Michigan) channel was eroded during Arkona time, lowering the lake level, and three separate ridges, designated Arkona I, II, and III, having crest elevations of 711, 700, and 695 feet were developed. Arkona ridges typically show poor development in northern Ohio and were not recognized by Carney (1910, 1911, and 1916) during early mapping of the ridges.

Arkona beach ridges are particularly well developed in Ashtabula County because Conneaut Creek and the Ashtabula River contributed large amounts of sediment for beach formation. The same is true for Lorain County, where the Vermilion and Black Rivers contributed sediment. Elsewhere, extensive sheets of sand rather than distinct ridges are common midway on the broad, gently sloping Middle (Whittlesey) Terrace surface separating the Lower (Warren) and Middle (Whittlesey) Cliffs. Consequently, the Arkona ridges are not associated with any cliffs, a fact which contributed to the late recognition of the Arkona strandlines.

In Lorain County, Arkona beaches tend to be discontinuous ridge segments, a mile or less in length and 500 to 1,000 feet wide. They are composed of sand about 5 feet thick. In Lake and Ashtabula Counties, the Arkona ridges are broad discontinuous subtle rises, which show distinctly on cross sections (fig. 30) as broad mounds that contain relatively large quantities of sand and gravel. It is not possible to follow a single ridge any great distance, and the ridges have a tendency to merge and then diverge again, adding to the difficulty of tracing strandlines.

The Arkona I ridge is 10 to 15 feet high and 1,500 feet wide in eastern Ashtabula County, where it blocked an earlier outlet of Conneaut Creek. Conneaut Creek was diverted 3 miles eastward to a low place in the Arkona I ridge. Four gravel pits are located in this segment of the Arkona I ridge.

The Arkona II ridge in eastern Ashtabula County is about ½ mile wide and 15 to 20 feet high. At least seven gravel pits are located in this ridge between Amboy and Kingsville, giving the Arkona II ridge the distinction of producing the best quality and largest quantity of gravel of any beach ridge in all of northeastern Ohio. At the large Gleason Sand and Gravel pit ½ mile southwest of Amboy, 8 feet of horizontally bedded medium to fine sandy gravel is exposed. The gravel deposit is slightly thicker than 8 feet, but a seasonally high water table limits excavation to 8 feet or less. At the Meade Sand and Gravel pit 1 mile northwest of Amboy, sand and gravel as much as 20 feet thick are exposed. A section through the center of the broad ridge showed 8 to 12 feet of gravel at the surface overlying 8 feet of sand, which rested on till. The gravel on the north slope of the ridge is much coarser and consists of pebbles and cobbles as large as 3 inches in diameter. Dune sand overlies the beach deposits in places, particularly in western Ashtabula County between Saybrook and Geneva. The Arkona ridges rise slightly toward the northeast in Ashtabula County, with Arkona I rising more than Arkona II, and Arkona II rising more than Arkona III.

WARREN BEACH RIDGES

A series of three ridges, designated Warren I, II, and III, with crest elevations of 686, 680, and 670 feet, were created as the level of Lake Warren fell in response to lowering of the Grand River (of Michigan) channel (Hough, 1958). The three ridges are grouped as a single complex ridge in some places; in a few places, particularly on broad flats, the three ridges are separate and well defined. The Warren ridge complex is located on the gently sloping Middle (Whittlesey) Terrace at the brow of the Lower (Warren) Cliff, and in places Warren beach deposits partially obscure the cliff. The composite Lower Cliff and Warren beach, known as North

Ridge, is the prominent ridge closest to Lake Erie and is followed by major highways, most notably U.S. Route 20 between Cleveland and the Ohio-Pennsylvania state line.

The Warren I beach in Lorain and western Cuyahoga Counties consists of a broad sheet of sand in places heaped into a broad ridge 5 to 10 feet high and 500 to 1,000 feet wide. The Warren II ridge, of similar proportions, occurs in proximity to Warren III, and it is not always possible to distinguish them as separate ridges. The combined ridges near Avon, Lorain County, contain one of the largest surface deposits of gravel in that county. Wood collected from the base of Warren I beach sand between Avon and Sheffield has a date of 13,050±100 radiocarbon years B.P. (ISGS-437). The Warren III ridge is not well developed in Lorain and Cuyahoga Counties because its crest elevation of 670 feet occurs near the brow of the prominent Lower (Warren) Cliff.

In Lake and Ashtabula Counties the Warren beach-ridge complex is 5 to 15 feet high, up to 2,000 feet wide, and is mantled in many places by irregular patches and ridges of dune sand, which increase the ridge height by 10 to 15 feet. The Warren beach sediment is predominantly sand, as evidenced in many small borrow pits in the ridge complex. The Warren beach-ridge complex rises less than 10 feet toward the northeast owing to glacio-isostatic rebound. Beach ridges in Ohio with elevations lower than the Warren complex show no effects of glacio-isostatic rebound (fig. 32).

OTHER BEACH RIDGES

Between the Lower (Warren) Cliff and the Lake Erie bluff is a wide, gently sloping, poorly drained terrace on which are situated numerous low sandy mounds, which have been variously interpreted as beach ridges, offshore bars, and dunes. These low mounds or ridges, each about 5 feet high or less, occur between the elevations of 660 and 612 feet, at 5- to 10-foot intervals (figs. 30, 32). These ridges are composed of sand, have a linear distribution parallel to the more prominent beach ridges, and probably represent a succession of short-lived strandlines formed as the lake level gradually lowered. Three of these ridges, Wayne (660 feet), Grassmere (640 feet), and Lundy (620 feet), have regional significance; the others may not be traceable beyond northeastern Ohio.

The Wayne beach is indistinct in most places in northeastern Ohio, primarily because its crest (660 feet) coincides with the Lower (Warren) Cliff. The only place the Wayne beach ridge is recognized with certainty is in eastern Ashtabula County, where a few low ridge segments with crests reaching an elevation of 660 feet occur a short distance north of the Lower (Warren) Cliff. The separation between cliff and beach ridge near the Ohio-Pennsylvania state line is due to the greater amount of glacio-isostatic uplift of the Lower Cliff and Terrace as compared to the beach ridge (fig. 33).

The Grassmere beach ridge, about 500 feet wide and 5 feet high, occurs close to the brow of the Lake Erie bluffs in eastern Ashtabula County, where it is traversed by Lake Road. The beach can be traced as a discontinuous ridge southwestward from Ashtabula into Lake County, where the beach becomes indistinct.

The Lundy beach ridge is characterized by very discontinuous elongate sandy mounds 5 feet high or less. The

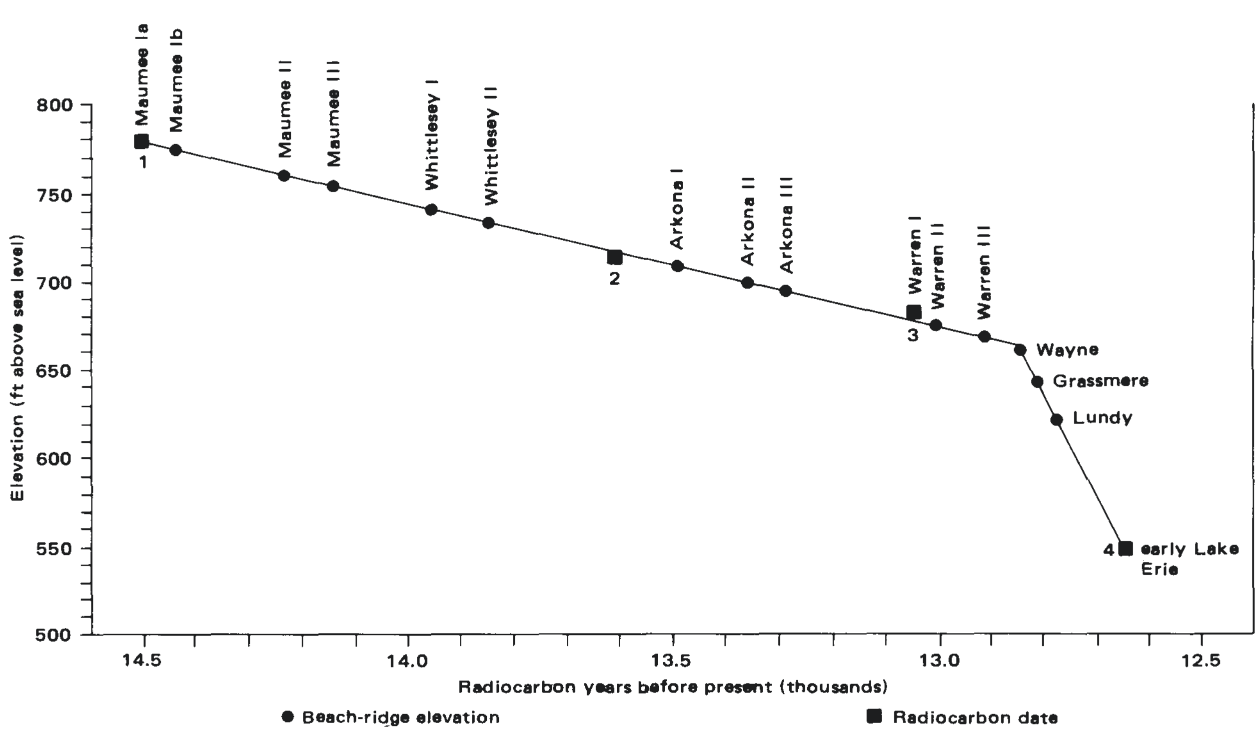


FIGURE 34.--Relationship between the elevations of beach ridges and their ages. The break in slope represents the change from the Grand River, Michigan, outlet to the Mohawk River, New York, outlet. Sources of carbon-14 dates: 1, ISGS-402; 2, W-33; 3, ISGS-437; 4, W-861.

mounds are primarily east of major streams and rivers.

CHRONOLOGY OF BEACH RIDGES

The chronology of the beach ridges, including both the order and dates of formation, has been the subject of disagreement for some time. Leverett (1902) assumed the chronological order of the beach ridges was the same as the topographical order, that is, that the ridges formed in simple sequence from highest to lowest as lake levels dropped due to the erosion of outlets and the opening of new, lower outlets. Taylor (*in* Leverett and Taylor, 1915), from a study of moraines in Michigan, devised a sequence that required rapid fluctuation of lake levels during which the Maumee III, Arkona I, II, and III, and Wayne beach ridges were submerged beneath rising waters that built ridges at higher elevations. Leverett and Taylor (1915) cited the "washed over" appearance of these ridges as confirming their submergence. This complex sequence, although later adopted by Hough (1958), is not supported by the evidence from northeastern Ohio.

As pointed out elsewhere in this report, the moraines in northeastern Ohio predate the last ice advance, and these moraines are not correlative with lake stages or beach ridges. The occurrence of coarse gravel overlying sand in the Arkona ridge is indicative of normal regression of lake level. If the beaches had been washed over and submerged, finer deposits would occur in the upper part of the beach deposits. Instead, the washed-over appearance of some beach ridges, such as the broad Arkona ridges in Ashtabula County, may be explained by the process of beach formation on a broad, very gently sloping terrace in response to a slight lowering of lake level owing to the erosion of the lake outlet.

The evidence cited does not preclude the possibility of fluctuating lake levels. It only signifies that the beach ridges preserved south of Lake Erie originated in a sequence according to their geographic and topographic position—the ridges are progressively younger toward the north, and the lower the elevation, the younger the ridge.

A few carbon-14 dates from northeastern Ohio offer some evidence of the chronological age of the beach ridges. Maumee beach-ridge formation was contemporaneous with the retreat of the Ashtabula ice sheet, and the earliest post-ice dates in northern Ohio are about 14,500 years B.P. (Totten, unpublished Medina County manuscript), suggesting deglaciation was well underway by this time. Wood collected by G. W. White from a horizon between the Whittlesey and Arkona beaches at Cleveland has a carbon-14 date of 13,600±500 years B.P. (W-33, Suess, 1954). Wood collected from basal Warren I beach gravel near Avon west of Cleveland has a carbon-14 date of 13,050±100 years B.P. (ISGS-437, Totten, unpublished Lorain County manuscript). The lake level dropped below the present Lake Erie level of 571 feet by 12,660 years B.P. (W-861, Lewis, 1969), the earliest date for early Lake Erie, and the lake level remained below 571 feet until recent time. A plot of the pertinent carbon-14 dates (fig. 34) suggests the decline of lake level was gradual and relatively constant from 14,500 years B.P. to about 12,900 years B.P., when the lake outlet was toward the west and while the prominent beach ridges were forming. From about 12,900 to 12,660 years B.P., the lake level dropped rapidly as a result of the opening of the Mohawk and Niagara outlets to the east in New York. The lake-level curve constructed from the radiocarbon dates (fig. 34) permits age assignment of the remaining ridges (table 7).

TABLE 7.—*Beach ridges of northeastern Ohio. Elevations are of ridge crests, and ages were determined from figure 34.*

Beach ridge	Elevation (ft)	Age (yrs B.P.)	Outlet
Maumee Ia	780	14,500	Wabash River, Indiana
Maumee Ib	774	14,450	Wabash River, Indiana
Maumee II	764	14,250	Wabash River, Indiana
Maumee III	753	14,100	Wabash River, Indiana
Whittlesey I	740	13,950	Grand River, Michigan
Whittlesey II	732	13,850	Grand River, Michigan
Arkona I	711	13,500	Grand River, Michigan
Arkona II	700	13,350	Grand River, Michigan
Arkona III	695	13,300	Grand River, Michigan
Warren I	686	13,050	Grand River, Michigan
Warren II	680	13,000	Grand River, Michigan
Warren III	670	12,900	Grand River, Michigan
Wayne	660	12,850	Mohawk River, New York
Grassmere	640	12,800	Mohawk River, New York
Lundy	620	12,750	Mohawk River, New York

Chapter 6

PLEISTOCENE HISTORY

INTRODUCTION

The Paleozoic sedimentary rocks of northeastern Ohio were uplifted at the end of the era, and erosion took place for about 200 million years, during the whole of Mesozoic and Tertiary time. At the end of the Tertiary Period, a time of lower temperatures and a persistence of snow ushered in the Pleistocene, or Glacial Epoch. The Pleistocene began possibly as much as 2 million years ago. At least four times (see table 1) during the Pleistocene, ice sheets formed over Labrador and spread out from this center. Evidence now accumulating indicates episodes of glaciation earlier than the four glacial stages that have been generally recognized. Ice flowed southwest into the basins of the Great Lakes and spread south into northeastern Ohio from the Erie basin.

Between each of the glacial stages the ice completely disappeared as the climate warmed, and weathering and erosion of the glacial deposits took place. During the last glacial stage, the Wisconsinan, the ice front fluctuated, advancing and retreating for distances of several hundred miles or even more. Similar advances and retreats in the three earlier glacial stages, the Nebraskan, Kansan, and Illinoian, also took place in the Mississippi Valley, but the evidence for such fluctuations in Ohio is not as clear.

The history of the advances and retreats in northeastern Ohio is determined from the deposits of the successive ice sheets and from the weathered zones upon the deposits. Later Pleistocene history, especially that of the Wisconsinan Stage, can be determined with a considerable degree of confidence because the deposits are more or less preserved. On the Allegheny Plateau, the pre-Wisconsinan deposits are thin and discontinuous, and hence the history of these stages is more conjectural than that of the Wisconsinan Stage. In contrast, in the central Mississippi Valley early (pre-Wisconsinan) Pleistocene deposits separated by interglacial deposits are well preserved in many places, and the history there is much firmer, although still not as detailed and secure as that of the later Pleistocene. On the Plateau of northeastern Ohio the early ice advanced into an area of considerable relief, and after the deposition of the earliest deposits a great deal of erosion took place, removing much of the material and leaving only the most meager remnants. The deposits cannot be traced continuously as can deposits of the later Pleistocene. The discussion of the earlier Pleistocene stages can therefore only be tentative and is based on the materials and observations in northeastern Ohio as well as in northwestern Pennsylvania (White, Totten, and Gross, 1969, p. 54-59).

The post-Yarmouthian episodes of ice advance, retreat, and erosional intervals are shown by a time-space diagram (fig. 35). The pre-Yarmouthian Pleistocene history cannot be shown for the Allegheny Plateau as it is so uncertain.

NEBRASKAN STAGE

Very early ice, possibly Nebraskan (or even earlier), dammed northward-flowing streams in Columbiana County; these streams were then flowing at higher levels than those of present valleys. Calcutta Silt, now preserved on uplands, was deposited at levels as high as 1,180 feet. The glacial origin of the Calcutta Silt is attested to by the presence of crystalline fragments that were not from local bedrock. Other valleys farther south were dammed by very early ice, and silt was deposited in them.

Meltwater from early glacial ice later than the first ice deposited valley trains in valleys with southward-flowing streams and in the Ohio River valley. Since deposition they have been mostly removed by erosion and only remnants at an elevation of 1,000 feet remain.

One or more very early glaciations, possibly Nebraskan in age, advanced into northeast Ohio to a limit south of the glacial boundary as presently mapped. Deposits of this advance now exist only as very sparse erratics in Stark and Carroll Counties.

AFTONIAN STAGE

During the Aftonian interglacial interval, weathering and erosion took place for a long time. The major part of the higher levels of Ohio River valley outwash dates from this time.

KANSAN STAGE

During a pre-Illinoian glaciation believed to be Kansan in age, till was deposited in northeastern Ohio. This till is now preserved in several places, most prominently near Elkton, Columbiana County. Meltwater from a Kansan ice sheet deposited outwash in the Ohio River valley; the outwash is preserved as small terrace remnants at elevations of about 850 feet. The Kansan Stage came to a close about 700,000 years ago with the advent of a warmer climate and a long interglacial stage.

YARMOUTHIAN STAGE

The Yarmouthian Stage was a lengthy time of erosion and weathering. Deep soils formed at this time in the Mississippi Valley are widespread, but such soils are known in northeastern Ohio at only a few places. The most complete deposit is at Elkton, Columbiana County. The intensity of this weathering indicates that the period in Ohio was of considerable length, similar to that farther west in the Mississippi Valley.

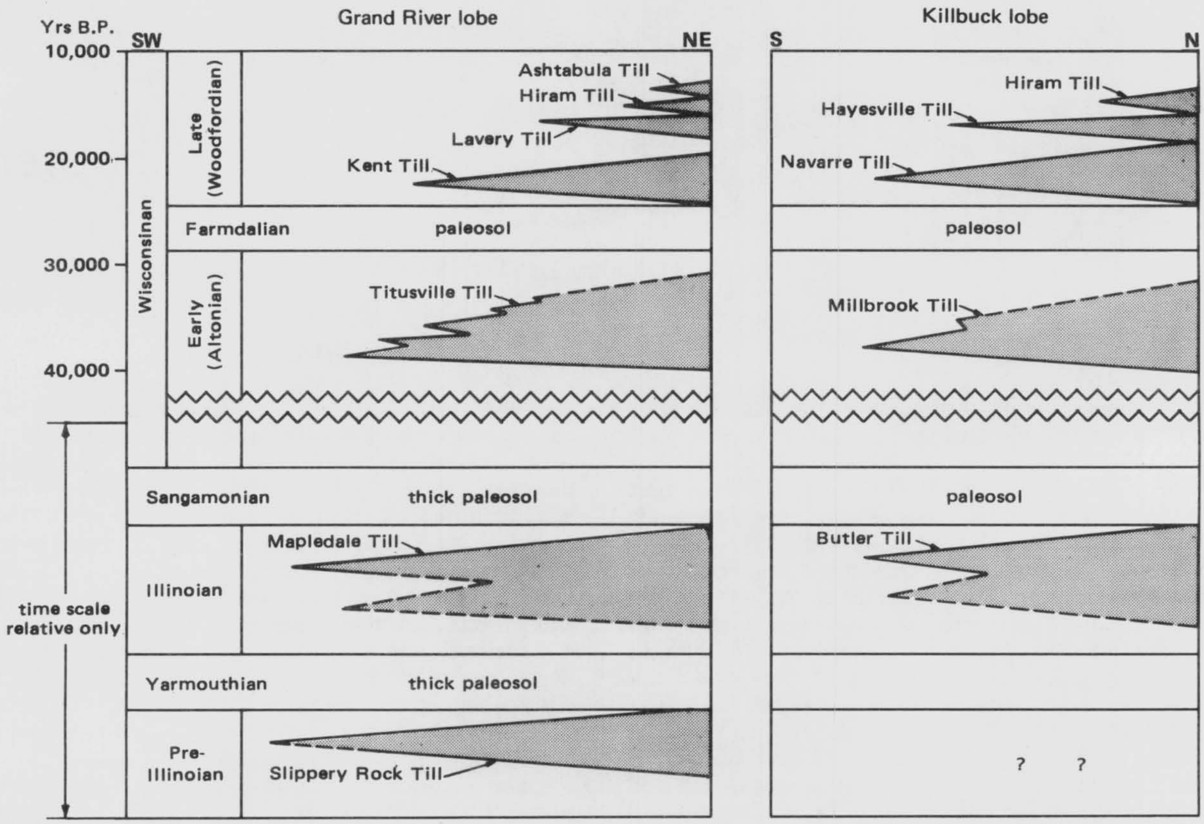


FIGURE 35.–Time-space diagram showing stratigraphic classification of tills in Grand River and Killbuck lobes (modified from White, 1969, p. 151, fig. 2). Thickness of each till wedge indicates relative time duration, not till thickness.

ILLINOIAN STAGE

About 125,000 years ago, Illinoian ice advanced into northeastern Ohio at least once and almost certainly more than once. In a very few exposures in the Grand River lobe, the Mapledale Till, underlying deposits of Wisconsinan age, is evidence of the advance of Illinoian ice. The Illinoian ice advanced south in the Grand River lobe in Ohio to essentially the same position as the earliest Wisconsinan advance, and in some places may have advanced as much as a mile or more beyond the Wisconsinan boundary. Farther east in Pennsylvania the ice which deposited the Mapledale Till advanced a mile to several miles beyond the Wisconsinan boundary.

In the Killbuck lobe the Butler Till, both at the surface and farther north in the subsurface, is evidence of an Illinoian ice advance. In this lobe the Illinoian ice advanced in Richland County to a line a little south of the farthest Wisconsinan advance.

In Richland, Summit, and Wayne Counties there is evidence of Illinoian advances prior to the deposition of the Butler Till; however, the deposits of these advances are so rare that little can be said about early Illinoian history.

SANGAMONIAN STAGE

A long, warmer interglacial climatic period known as the Sangamonian Stage followed the retreat of the Illinoian ice. This interglacial interval is represented by a weathering profile developed on the Mapledale Till and associated deposits of the Grand River lobe and on the Butler Till of the Killbuck lobe. The length of the Sangamonian Stage is indicated by the erosion of a large part of the Illinoian deposits before the advance of the Wisconsinan ice.

WISCONSINAN STAGE

After the Sangamonian Stage of weathering and erosion, ice again formed over Labrador and about 70,000 years ago advanced down the Ontario and Erie basins and spread onto the Allegheny Plateau. Several prominent sets of till sheets were deposited, one in the early Wisconsinan, the Altonian Substage, and the others in the later Wisconsinan, the Woodfordian Substage. In extreme northeastern Ohio an earlier till, the Keefus Till, occurs below the Titusville Till of Altonian age. The age of the Keefus is not completely established, but it may be of a very early, pre-Altonian Wisconsinan age. It is a distinctive red till and occurs only in the subsurface in Ashtabula and Lake Counties.

Figure 5 shows the ice margins in the Wisconsinan Stage. Figures 36-40 show separately the positions of the ice for each advance.

ALTONIAN SUBSTAGE

The Titusville Till and the correlative Mogadore, Millbrook, and Jelloway Tills were deposited by ice which advanced out of the Erie basin about 40,000 years ago.

Unlike later ice advances, this ice sheet was able to overcome topographic irregularities and advance to a general east-west line across Columbiana, Stark, Holmes, Ashland, and Richland Counties (fig. 36). It was this advance which deposited by far the thickest drift on the Allegheny Plateau. Very large quantities of gravel in the form of kames and kame terraces were deposited; essentially all commercially exploited gravel in the Allegheny Plateau is of this age.

A second episode in the advance of this Altonian ice came after an unknown time of ice retreat had taken place by downmelting and stagnation. The Altonian ice readvanced to a line across southwestern Ashtabula, central Trumbull, northwestern Portage, north-central Summit, southeastern Medina, northwestern Wayne, northern Ashland, and northern Richland Counties (fig. 36). The deposition of this pulse is in marked contrast to the style and topography of the earlier advance. In the earlier advance the drift formed an irregular nonlinear hummocky topography; in the second advance the drift formed end moraines in the outer 10 to 15 miles. This episode ended by a final surge, which produced the Defiance Moraine.

It must be kept in mind that the end moraines, including the Kent Moraine of the Grand River lobe, the Summit County moraine complex, and the Buck Hill Moraine of the Killbuck lobe, have a covering of till of later ages. Wherever outcrops of sufficient thickness are available, it can be seen that the later tills that form the surface of the end moraines are only a more or less thin veneer over the

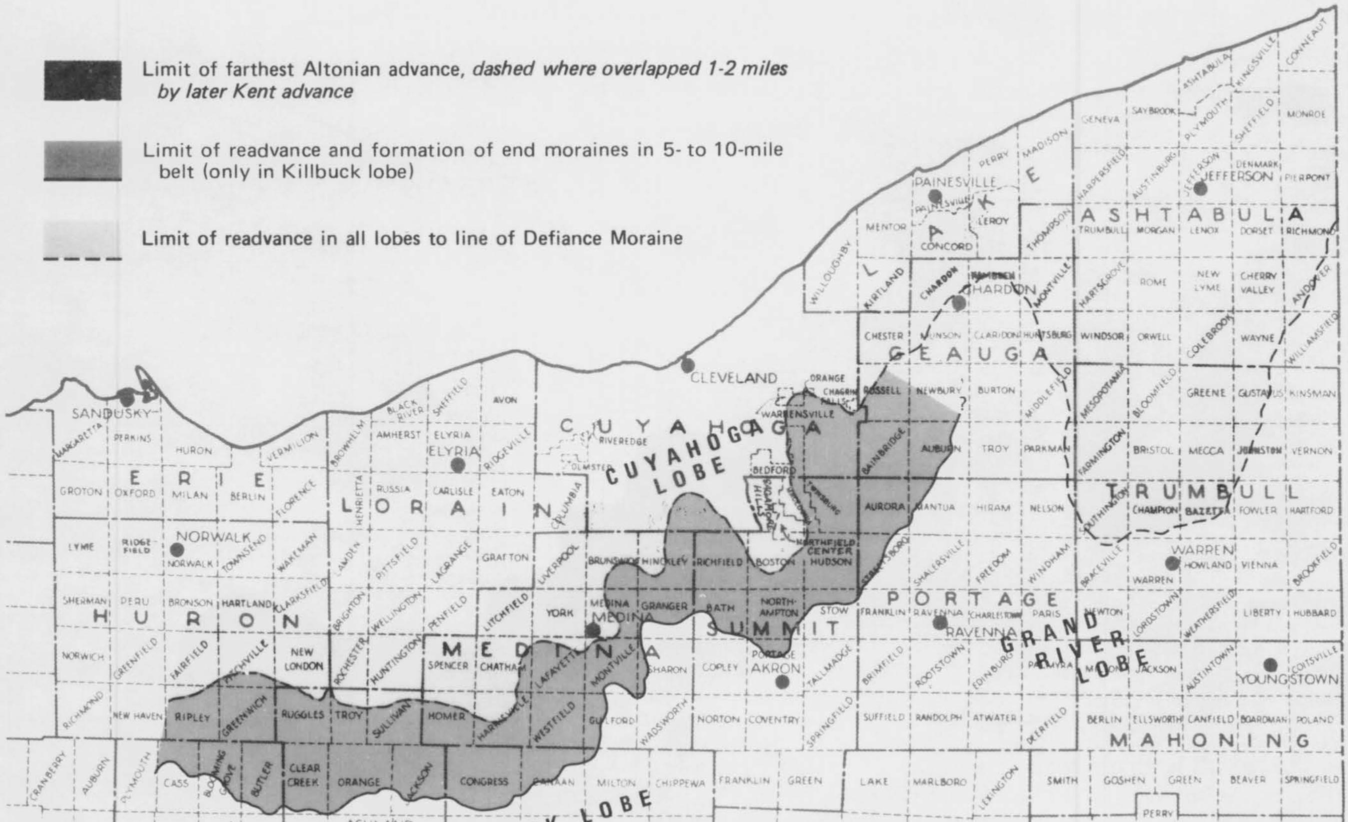


FIGURE 36.–Altonian (Titusville-Mogadore-Millbrook-Jelloway) ice margins in northeastern Ohio. Altonian drift is covered by later tills except in a narrow outer belt on the east and west. End moraines are covered by later tills but moraine ridges are clearly prominent.

main mass of Altonian-age tills (fig. 21) that form the cores of the moraines. This multiple character of the end moraines is becoming more and more evident in other areas from more detailed subsurface work in drilling and excavation (see Wickham, 1977).

FARMDALIAN SUBSTAGE

After the retreat of the Titusville-Mogadore-Millbrook ice sheet, a period of weathering and erosion lasting several thousand years followed. In northeastern Ohio the only datable material, at Garfield Heights near Cleveland, indicates that the Farmdalian Substage there began about 28,000 years ago and ended with the advance of the Kent ice about 23,000 years ago.

WOODFORDIAN SUBSTAGE

Kent-Navarre advance

The Farmdalian Substage was brought to a close by the readvance of ice from the Erie basin about 23,000 years ago. This earliest Woodfordian advance in northeastern Ohio was in separate lobes—the Grand River lobe in eastern Ohio, the Killbuck lobe in east-central Ohio, and a small lobe between them, the Cuyahoga lobe (fig. 37). The western margin of the Grand River lobe was in extreme eastern Summit County and north-central Stark County. The eastern margin of the Killbuck lobe was in eastern Medina County, extreme northeastern Wayne County, extreme southern Summit County, and east-central Stark County. The margins of the

FIGURE 37.—Early Woodfordian (Kent-Navarre) ice margins in northeastern Ohio. Note the ice-free area in southern Summit County at this time and the position of the Cuyahoga lobe.

Grand River and Killbuck lobes joined in extreme southeastern Summit County and northern Stark County. It may be noted that in southern Summit County and northwestern Stark County the ice in the Killbuck lobe was actually moving northward toward the margin of the lobe.

The southern part of Summit County was not invaded by this earliest Woodfordian ice advance. This left a window in the Summit County region in which the Altonian drift was never covered by later deposits. The surface till in this area is the Mogadore Till.

The Kent Till, deposited by the Grand River lobe, and the Navarre Till, deposited by the Killbuck lobe, are correlative, but the exact synchronism of advance cannot be established. It is possible that, in the interlobate area where the two lobes joined in Summit and Stark Counties, one advanced a bit earlier than the other, so that there may never have been a time in which an open space existed between the two lobes to form a true interlobate moraine. The Kent and Navarre Tills (earliest Woodfordian) are generally thin so that the bulk of the drift, including that in the Kent Moraine, is actually pre-Woodfordian.

The margin of the Navarre Till in Summit and Medina Counties lies beneath the later Lavery Till, but inasmuch as that till is very thin and discontinuous, the margin of the Navarre Till can be quite well determined (fig. 37). The margin of the earliest Woodfordian till in the small Cuyahoga lobe is just within the margin of later tills; it cannot be determined much closer than 1 or 2 miles.

The Kent and Navarre Tills were deposited by an ice sheet which was dissipating over a considerable marginal

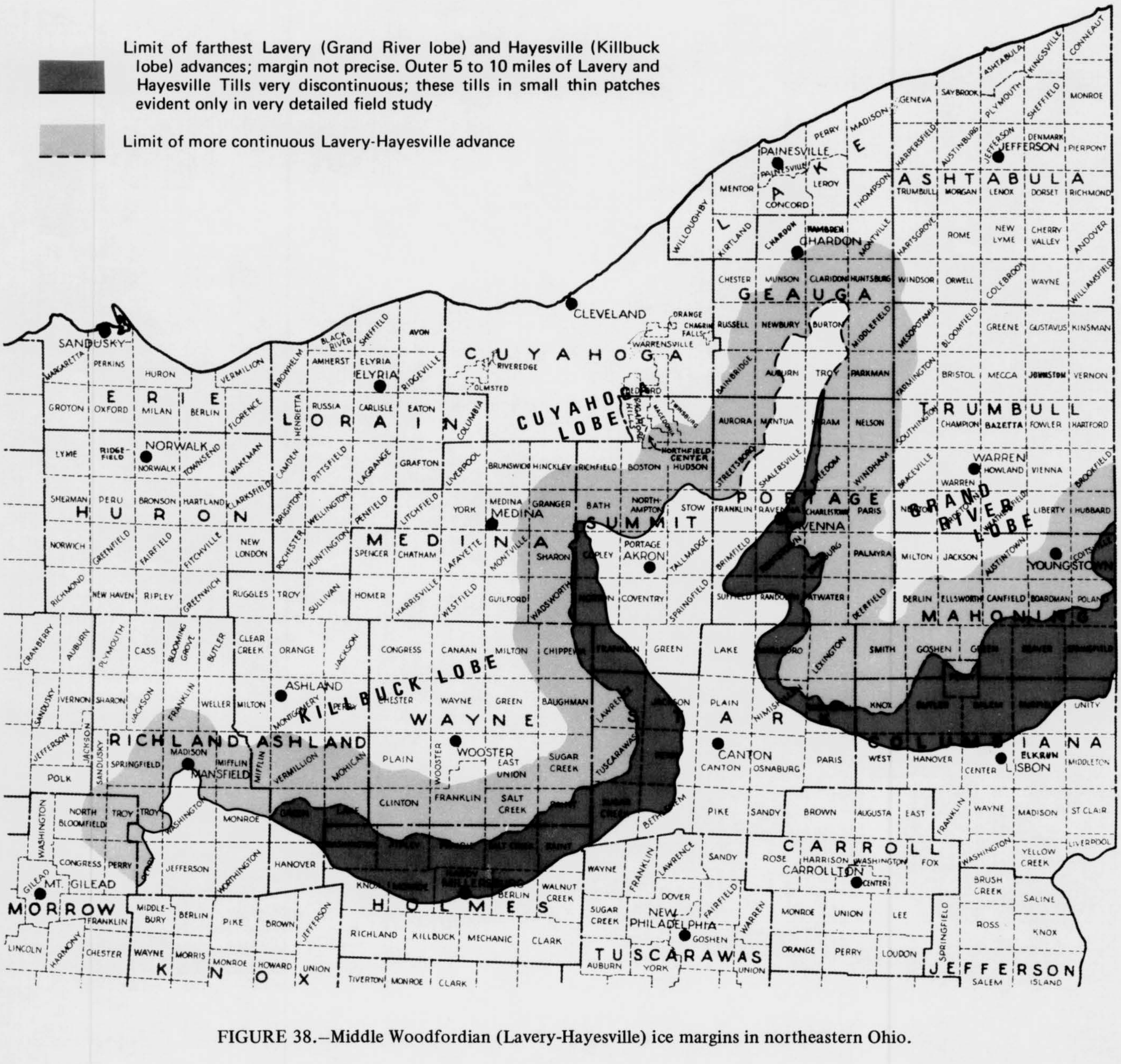


FIGURE 38.–Middle Woodfordian (Lavery-Hayesville) ice margins in northeastern Ohio.

belt. Meltwater drained along the sides of ice masses and deposited sand and gravel, which are associated with the much larger kame terraces of earlier Titusville age. Generally it is possible to distinguish between the two gravels. The later deposits are much thinner and overlie the earlier thicker gravels. The Kent-Navarre ice disappeared about 20,000 years ago, retreating at least into the Erie basin.

Lavery-Hayesville advance

The time of the next advance of Woodfordian ice, the Lavery-Hayesville advance, is not precisely known, but it may have taken place about 19,000 years ago. This ice advanced in the Grand River lobe, the Killbuck lobe, and in the smaller Cuyahoga lobe (fig. 38). The Lavery-Hayesville advance stopped 1 to 5 miles short of the earlier Kent-Navarre advance except in southwestern Summit and southeastern Medina Counties, where the Hayesville ice advanced beyond the margin of the Navarre Till. A notable feature of the Lavery-Hayesville advance was the deposition of a marginal belt of thin discontinuous small deposits, so inconspicuous that their presence was not immediately discovered. The Lavery-Hayesville Tills in this marginal belt (fig. 38) are so scanty that earlier material almost everywhere forms the actual surface. From 5 to 10 miles within the margin of the thin Lavery-Hayesville, these tills are thicker and form a more or less continuous cover over the underlying material. The Lavery-Hayesville ice disappeared without leaving outwash deposits of significance.

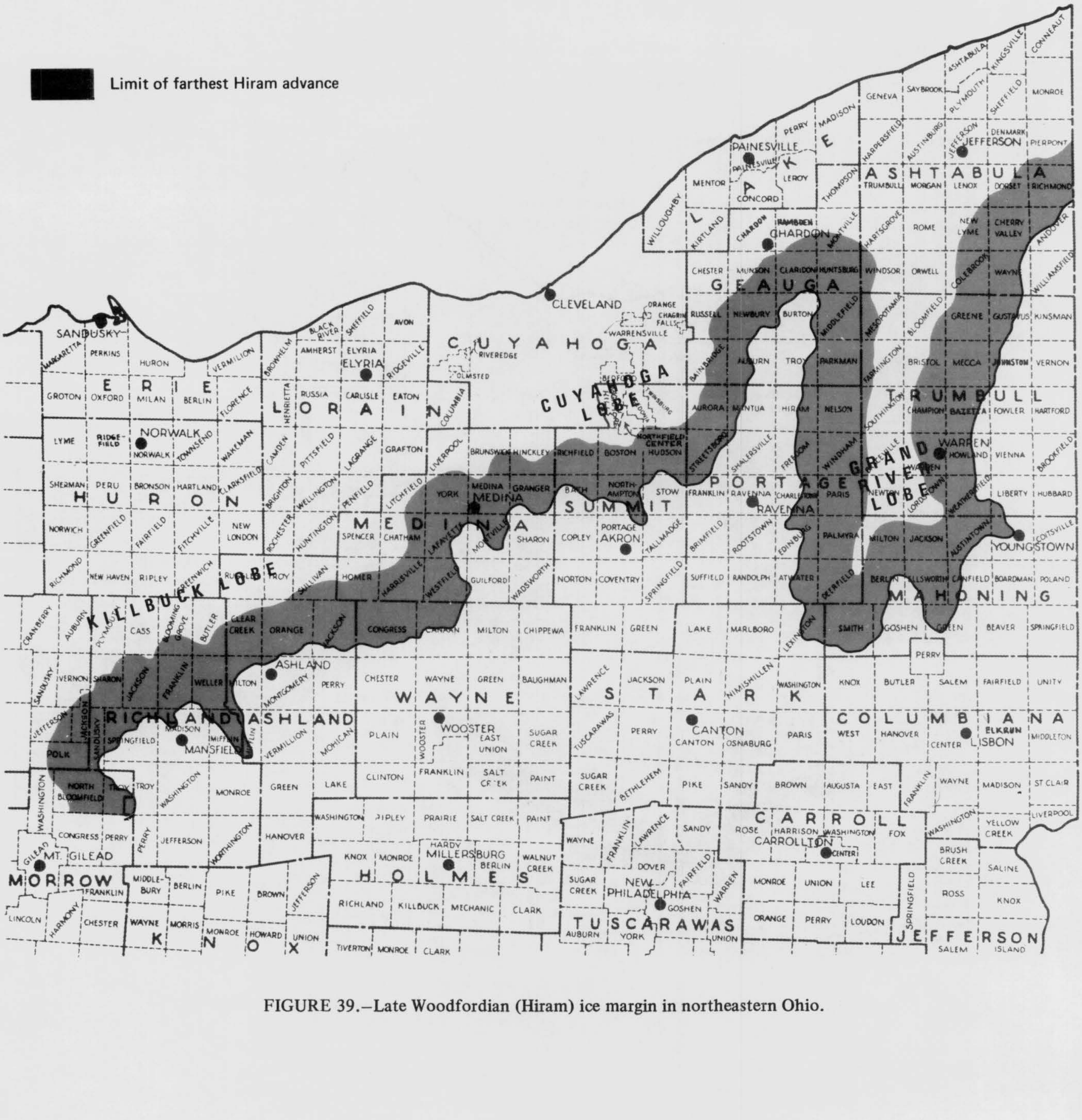


FIGURE 39.–Late Woodfordian (Hiram) ice margin in northeastern Ohio.

Hiram advance

Except in a narrow belt along Lake Erie, the last ice to invade Ohio was the Hiram advance, which formed a continuous line across northeastern Ohio. The margin was very irregular because the Hiram ice was thin and delicately controlled by topography (fig. 39). This ice sheet did not extend quite as far as the somewhat earlier Lavery-Hayesville ice, except in Northampton Township, Summit County, where it extended beyond the limit of Lavery ice in a small area in the city of Cuyahoga Falls. The Hiram ice deposited a generally thin layer of clay till, in many places so thin that the present soil is actually formed from the earlier Lavery Till.

The Hiram ice dissipated from slow downmelting; in some places meltwater accumulated upon the ice in very shallow ephemeral lakes and ponds in which silt and clay accumulated in thicknesses from a few inches to as much as 2 feet. It is difficult to distinguish this material from the till because soil-forming processes have altered the surficial material. Water from melting Hiram ice deposited almost no sand or gravel; gravels which are sometimes evident in the region of Hiram Till are actually of an earlier age.

The character of retreat and dissipation of the Hiram ice is well shown in Summit County. Meltwater from Hiram ice accumulated beyond the ice edge in the Cuyahoga River valley and in the area from Fairlawn, Summit County, as far south as Barberton, forming either shallow lakes or very sluggish wide streams in which silt was deposited. Most of the meltwater came from the top of the waning ice in the

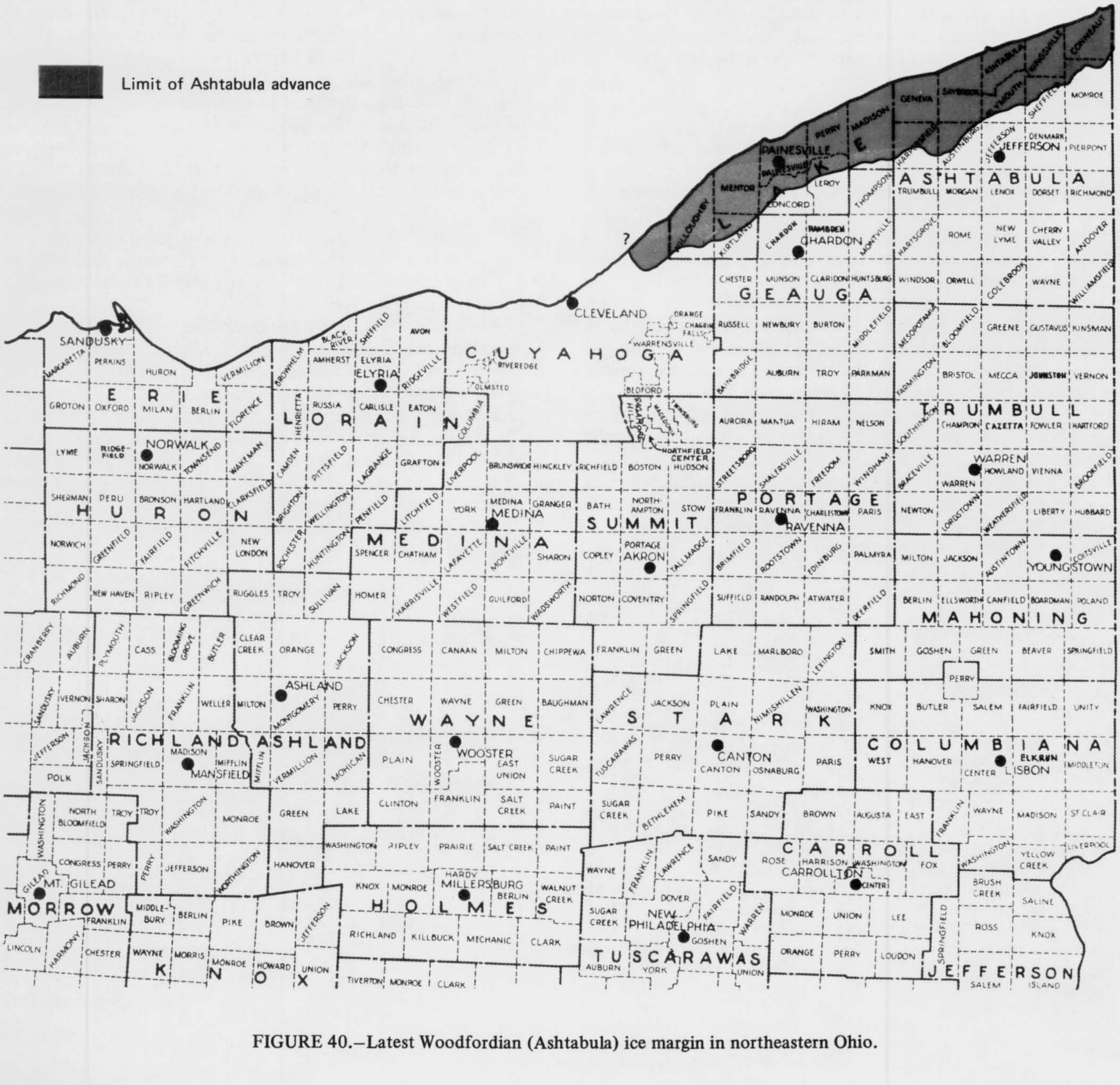


FIGURE 40.–Latest Woodfordian (Ashtabula) ice margin in northeastern Ohio.

north-central and northeastern parts of Summit County and not from a definite clifflike ice front. The meltwater flowed to the Cuyahoga River valley to form a lake at an elevation of 1,000 feet extending south to the present site of Summit Lake. The silt and fine sand that accumulated in this lake now form the surface material in much of Akron on either side of the Cuyahoga River and southward through central Akron to Summit Lake. Some silt was carried southward from Summit Lake to the Tuscarawas River valley and thence along the Tuscarawas River far beyond Summit County.

Silty water from the waning Hiram ice in western Summit County flowed southward and southeastward in the Shockalog Run depression to the Tuscarawas River valley by way of the Copley Marsh depression and the Wolf Creek depression to Barberton. The extensive deposits of silt and fine sand were sufficient to fill or partly fill some of the kettle holes in the lowlands, and considerable thicknesses of silt are encountered in borings and excavations. However, some gravel kames of Mogadore age rise as islands above the general 1,000-foot level of the silt deposits. In places where the kames are just below 1,000 feet, large masses of gravel are present below a thin veneer of silt.

In Columbiana and Mahoning Counties thin silt deposits lie upon the Hiram Till. In northwestern Columbiana County, east and southeast of Alliance, silt was deposited in a lake which drained southward through a spectacular gorge across the divide near New Alexander.

In the Killbuck lobe, superglacial deposits are most noticeable in the Black Fork valley. In this valley a tongue of ice extended southward in western Ashland and eastern Richland Counties beyond Mifflin. Silt was deposited in small shallow ponds here and there upon the melting ice, but no lake was formed in the valley south of the ice tongue because southward drainage had been established earlier.

After the Hiram ice had dissipated, drainage northward to ancestral Lake Erie was established, and the water in the lake in the Cuyahoga River valley dropped to about 800 feet, the level of early Lake Maumee. This lake at 800 feet then became an arm or fiordlike extension of Lake Maumee and extended from north-central Akron and the base of the falls of the Cuyahoga northward to Cleveland (Claypole, 1887). Streams flowing down the valley walls to the Cuyahoga River valley and from the uplands into the lake deposited deltas at the 800-foot elevation; alluvial fans at places rose above the delta proper. The deltas are composed of gravel and sand with some silt layers at places. In the center of the valley, clay and silt accumulated, but in places layers of sand were deposited.

There were also lower post-Hiram water levels in the Cuyahoga River valley; these levels were extensions of Lake Whittlesey and later lakes. Deltas also were formed in these water bodies.

Ashtabula advance

After the Hiram ice retreated beyond northern Ohio, probably beyond the Erie basin, ice once more advanced. It reached a line only 5 to 8 miles south of the present shore of Lake Erie; its western limit was in eastern Cleveland, where the ice front turned north across the present Erie basin (fig. 40). This advance deposited the Ashtabula Till, which is composed of a high proportion of ground-up shale from the bottom of the lake and hence is highly illitic.

The Ashtabula ice deposited a thick wedge of till against a cliff at about the position of the present Lake Erie bluff, and one or more such wedges against higher cliffs of earlier lake stages. On the smooth, gentle slopes in front of the cliffs only thin Ashtabula Till was deposited over earlier tills or over the bedrock. The Ashtabula ice deposited a more or less thin veneer of till over the Ashtabula, Painesville, and Euclid Moraines.

The Ashtabula ice dammed the northward-flowing Grand River to form two successive lakes in Ashtabula and northern Trumbull Counties. The first, Rock Creek Lake, was short lived and drained eastward across Trumbull County to the Mosquito Creek basin and thence southward to the Mahoning River. The second, lower lake, Grand River Lake, came into existence when a passage became available to the west between the Euclid and Painesville Moraines as far as Painesville, where the water entered early Lake Maumee. Continental ice did not invade Ohio after the withdrawal of the Ashtabula ice.

Chapter 7

MINERAL RESOURCES

INTRODUCTION

The mineral resources of the bedrock in northeastern Ohio do not form a part of this report on glacial deposits. In northeastern Ohio extensive and valuable deposits of coal, clay, salt, limestone, shale, sandstone, and oil and gas are present. Extensive and detailed information on these resources may be found in the many reports of the Division of Geological Survey which have appeared from 1838 to the present. In addition to the published reports much additional information is on open file at the Survey offices.

The glacial deposits of northeastern Ohio have great economic importance, and with the increasing number of highways, large structures, housing developments, and surface modifications, the nature and extent of the glacial material become more and more critical. The glacial drift contains extensive deposits of sand and gravel and vital ground-water supplies. Glacial clays are used in the ceramic industry, although they have been more important in the past. Certain parts of the glaciated area are attractive for recreational purposes. The widely different engineering and environmental characteristics of the various deposits are assuming ever greater importance. The geologic information in this report will provide a technology base for integrated land-use planning.

In addition to the county glacial reports listed on p. 5, specific reports on sand and gravel resources and land-use suitabilities have been published by the Ohio Survey for some counties and are in press or in preparation for others. The information from all these studies and reports is useful in locating areas for specific site study, as well as indicating areas that are unsuitable for certain purposes, thus saving time and resources.

SAND AND GRAVEL

Deposits of sand and gravel are widely distributed in northeastern Ohio. They have been important in the past, and their importance will continue. Sand and gravel are used as aggregate in concrete, in road building, and for other uses. As several large cities and many smaller ones are located in the area of this report, the problem of gravel for concrete aggregate and for other construction becomes ever more pressing. Supplies have to be transported longer and longer distances as available supplies near cities become exhausted. These critical resources warrant detailed study for the determination of all possible supplies and for the environmental provisions that will make these vital materials available for use. Although sand and gravel are present in every county, they are present in largest amounts in the counties in which the Altonian tills and the early Woodfordian tills and their associated outwash are at or close to the surface. North of the surface area of these tills the Altonian sand and gravel may be present but are buried. The sand and gravel are in kames, kame terraces, and valley trains. Some alluvial sand is present, but is economically unimportant.

Perhaps the most important sand and gravel deposits are in kames and kame terraces. These deposits have already been described and their location is shown on plate 1. The most extensive and widely exploited sand and gravel deposits are in the great area of kames and kame terraces in Stark, Summit, western Portage, and central Geauga Counties. Many of these deposits are associated with the kame elements of the Kent and Buck Hill Moraines. However, these deposits are in the Canton-Akron urban, suburban, and exurban area and large parts of the gravel-rich areas have been built upon or zoned in such a way that it is becoming more and more difficult to extract the sand and gravel.

Other areas of kames and kame terraces are in southern Mahoning and northern Columbiana Counties, in the Pymatuning Creek valley of Ashtabula and Trumbull Counties, in southern Medina County, and in parts of Wayne, Holmes, Ashland, and Richland Counties.

Valley-train outwash may extend below the present stream in a valley, and in some valleys it may be tens or even a hundred feet or more thick and coarser than the material at the surface. An example of a large gravel operation in valley fill below the water table is in the Killbuck Creek valley south of Wooster, Wayne County; the gravel is excavated below the water table by scraper (White, 1967, p. 31). A similar operation north of Kent, Portage County, has produced large quantities of gravel by the use of dredges.

Unlike kame terraces, which formed only in the once ice-covered area, valley trains extend beyond the glacial boundary as partially eroded terraces above the streams and as valley fill below the present streams. The terraces are at different heights because the material was deposited at various times. The valley fill and the terraces may have large supplies of sand and gravel. The terraces in the valleys of the Mohican, Walhonding, and Tuscarawas Rivers and Killbuck, Sandy, and Beaver Creeks are important sources of sand and gravel, both above and below the water table.

As the major sand and gravel deposits are Altonian in age (Titusville-Mogadore-Millbrook), it must be emphasized that north of the outcrop area these deposits are covered by one or more tills of Woodfordian age, ranging in thickness from a very few feet to many tens of feet. As the till cover becomes thicker it is increasingly difficult to map the sand and gravel, but large supplies may exist under heavy cover.

Concealed kames are present in some of the areas of hummocky topography without linear trend in Summit and Columbiana Counties and other counties. The cores of many end moraines have some sand and gravel; some of them are buried kame moraines. In Ashtabula County, well records indicate that potentially large sand and gravel supplies exist under 5 to 50 feet or more of till cover (White and Totten, 1979). The exploitation of such buried sand and gravel would require adequate capital for a program of detailed exploration by drilling and geophysical methods and for the acquisition of sufficiently large areas of land for an extensive operation, including disposal of spoil and restoration of the land surface. Any development of sand and gravel resources requires the cooperation of operators and local government and planning agencies so that the best use is made of the land. Planned multiple land use allows extraction of the sand and gravel followed by proper reclamation so that the area is then suitable for recreational or residential use.

CERAMIC PRODUCTS

In pioneer days glacial deposits were used for making bricks and drain tile in almost every county. There still remain older farmhouses made of bricks of local material, some of it from the excavations for the building and burned in temporary kilns with wood from the property. The first building of Ashland College was constructed in 1878 of "brick made on the grounds" (Miller and Mason, 1953, p. 18). The material was Hayesville Till, but probably included more sandy lower tills—Navarre and Millbrook.

Both lake clays from the Lake Plain and till from the Plateau have been used for ceramic products. It is not likely that these clays were used for crocks and similar ware because these products require clay that can be burned at a higher temperature than can the glacial clays. Glacial clays also will not withstand the higher temperatures required for salt glazing. In his report on surface clays of Ohio, Lamborn (*in* Lamborn, Austin, and Shaaf, 1938, p. 220-257) described the use of glacial materials for brick, drain tile, and hollow building tile in several northwestern Ohio counties. Complete analyses of the material are included and give an idea of the properties to be expected from lacustrine or glacial clays in northeastern Ohio. No modern commercial use of glacial clays in northeastern Ohio is known at present. In the central and southern parts of northeastern Ohio, deposits of clay of Pennsylvanian age (see fig. 3) have been used at many localities (Stout and others, 1923) and are still being used. The quality of the ware made from these clays is excellent, and glacial clays cannot compete at the present time with these materials.

A possible minor use of glacial clays from northeastern Ohio is for the production of art pottery. These clays burn at a relatively low temperature in the kiln. The green ware must be dried and fired with great care to prevent cracking. The best apparent burning range for glacial clays is generally from about 1,050°C to 1,125°C (1,925°F to 2,050°F), temperatures attainable in a local potter's small kiln. The Division of Geological Survey has many analyses on file which could be used to guide potters in the quality and characteristics of the clays that might be expected.

WATER SUPPLY

Northeastern Ohio has abundant supplies of ground water in both the bedrock and the glacial drift, but the supplies are unevenly distributed. Details are set forth in water-resources reports, such as those on Cuyahoga County (Winslow, White, and Webber, 1953), Portage County (Winslow and White, 1966), and Summit County (Smith and White, 1953). An earlier report by Stout, Ver Steeg, and Lamb (1943) contains some general information (also see Smyth, 1979). Ground-water resources maps of all the northeastern Ohio counties have been published recently by the Ohio Department of Natural Resources, Division of Water. In addition, records of the many thousands of wells that have been drilled and logs of the materials encountered and water quantity are on open file at the Division of Water.

The largest water supplies are in the drift deposits in the buried valleys, some of which are now occupied by streams. If the drift filling is porous and permeable, very large supplies can be obtained, particularly if the present stream in a valley provides recharge as pumping takes place. However, because the stratigraphy of the drift—layers of gravel, sand, silt, clay, and till—in the buried valleys is highly variable, there may be considerable variation in the yields of wells. Exploratory drilling will disclose the character of this variation.

End-moraine and other hummocky areas may have water-bearing gravel at depth, as shown by the hundreds of sections illustrated in Smith and White (1953). Ground-moraine areas are generally not favorable for water supply.

Detailed information from published and open-file records furnishes guidance for consultants to municipalities and industry. A detailed study of existing well records will indicate areas where water supplies are favorable for development. Where conditions are not favorable for water in the glacial drift, the rock below the glacial drift may be capable of supplying satisfactory water supplies.

Chapter 8

ENVIRONMENTAL AND ENGINEERING GEOLOGY

INTRODUCTION

Engineering geology is concerned with the application of geological information in activities of man, especially activities that deal with alteration of the earth's surface or material. In the preceding descriptions and discussions the relation of the topography and material to use by man has been expressed or implied. All environmental changes involve more or less engineering manipulation of earth materials.

VERTICAL VARIATION IN DRIFT MATERIALS

As larger and larger structures are built, deeper foundations are required, and the engineer is concerned with the vertical variations that may be encountered at various depths (White, 1972; 1974, p. 346-347). The stratigraphic units that may be encountered in northeastern Ohio have already been described and are illustrated in some of the diagrams. In metropolitan areas, and soon between such areas, tunneling rather than open cutting will become more common for large sewer lines and other purposes. It is necessary to realize that conditions may change laterally as well as vertically; such changes will influence the speed of advance and the equipment required.

In planning the material for fills for highways, dams, and other structures, it is necessary to consider that the various tills differ in many properties. The surface till probably does not have the same properties as the tills which make up the bulk of a deposit. Surface till that makes a satisfactory fill material may be only a few feet thick and overlie quite different material.

Planning for liquid- or solid-waste disposal sites also must consider the character and variation of the glacial deposits.

A variety of problems in water supply and control is associated with movement, or retarding of movement, of water through tills. For example, building of a dam upon glacial deposits requires an understanding of the anatomy of the deposits to assure a proper program of exploration, planning, and construction of the dam and its reservoir.

LANDSLIDES

The susceptibility of materials to slumping and landsliding in different topographic and geologic situations was described and illustrated as early as 1838 by Mather (1838, p. 16-18, fig. 2; White and Legget, 1981) and the first Geological Survey of Ohio. The clay- and silt-rich Hiram and Lavery Tills require particularly careful engineering attention based on their geological character. Piping may occur when interfaces separating tills are exposed.

Some of the deep valleys of streams flowing to Lake Erie are extensive scenic areas, but they are also the areas with the severest constraints for buildings and other structures. The valleys of the Cuyahoga, Chagrin, Grand, and Ashtabula Rivers and Conneaut Creek are examples of such gorgelike valleys. The interbedded till sheets (mostly clayey and silty till) and lacustrine clays form especially unstable slopes, either natural or manmade. The most favorable use of the rugged land of the gorges is for recreational purposes. The Cuyahoga River valley between Akron and Cleveland is now the Cuyahoga Valley National Recreation Area. Parks have wisely been established in many of the other deep valleys.

The engineering geology problems of these areas are severe. The slopes are unstable, and road construction requires very special measures to insure stability where the slopes are cut into different layers of unconsolidated material (soils in engineering terms). These materials differ in permeability, and water may flow out at interfaces and localize areas of slumping. Examples of slumping may be seen along all the steep valleys in northern Ohio where construction has taken place on slopes and on slope margins.

An added engineering problem in landslide-prone areas is layered material that is high in silt and clay, but in different proportions. Such material may have differing rates of compaction.

BOULDER PAVEMENTS

A feature that has not been recognized in the past is boulder pavement that may be present at the interface of two tills. This feature is not a nest of boulders, but an actual layer that may have considerable lateral extent. As more and more exposures are studied in deep excavations and in tunnels, it becomes apparent that boulder pavements are far more common than generally was realized (White, 1974, p. 336). When boulder pavements are encountered in tunneling, the tunneling machine generally cannot deal with a continuous layer and the machine may be damaged. The possible presence of boulder pavements must be considered in the preliminary investigation for large projects. Figures 21 and 26 illustrate examples of boulder pavements in northeastern Ohio.

ENVIRONMENTAL ASPECTS OF GEOMORPHIC AREAS

GROUND MORAINE

The areas of ground moraine are mainly on the uplands. The surface ranges from level to slightly undulating, and surface drainage may be slow. The drift on the uplands is thin, and bedrock may be very close to the surface. This situation must be taken into account in excavations. The material of the ground moraine is unsuitable for waste disposal (for example, Van Horn, 1976).

END MORAINES AND OTHER HUMMOCKY TOPOGRAPHY

The very extensive hummocky areas are similar to each other in surface form, but differ in drift composition. The surface drainage is good except for the depressions, which may be the sites of swamps or lakes. These rolling areas are attractive home sites, as shown by the widespread suburban development throughout much of Stark and Summit Counties and parts of Richland, Medina, Portage, and other counties.

Engineering problems in hummocky topography are not severe, but it must be kept in mind that although the drift of these areas in the northern counties is clayey and silty till at the surface, the material a very few to many tens of feet below the surface may be gravel and sandy till. Thus in an excavation of any depth, different materials will be encountered.

The most suitable areas for solid- and liquid-waste disposal are in some of the hummocky areas where silty clay and till, 50 feet or more thick, are present at the surface (for example, Van Horn, 1976). Other areas of hummocky topography may be more or less marginally suitable for waste disposal.

KAMES AND KAME TERRACES

The large hummocky areas of sand and gravel in kames and kame terraces in northeastern Ohio provide a great variety of environments. Kames and kame terraces at lower levels have a high water table, whereas at higher levels the water table may be a considerable distance below the surface. In general drainage is good except at lower elevations, where swamps or lakes may be present in depressions.

The engineering problems in areas of kames and kame terraces are connected with the position of the water table. Foundation conditions are generally good, but the possibility of pockets of silt or till should be realized.

Kame and kame-terrace areas are unsuitable for waste disposal because of their high permeability.

VALLEY TRAINS

In many of the valleys in northeastern Ohio, valley trains are present below the kame terraces, as already described. The material is generally finer than that of the kame terraces; much of it is sand rather than gravel. The valley trains are generally not far above the present streams, thus the water table is close to the surface.

OUTWASH PLAINS AND LAKE PLAINS

Outwash plains and lake plains are composed of sand and silt, are generally at low elevation, are subject to flooding, and have a high water table. These areas are unsuitable for waste disposal.

SWAMPS AND KETTLE HOLES

The bottoms of many depressions in the glacial drift of northern Ohio are at or below the level of ground water. Those below ground-water level are lakes and those at ground-water level are swamps. These lakes and swamps represent the filling of once deeper depressions by organic matter, now peat, or muck if mixed with clay and silt. The thickness of peat deposits may be as much as 40 feet. The aspect in 1912 of some of the bogs is described with accompanying maps, photographs, and analyses by Dachnowski (1912). These bogs in pioneer days, and some as recently as 50 years ago, were the sites of cranberry marshes or tamarack bogs (Dachnowski, 1912, pl. 4). Almost all have now been drained and are used for growing crops, generally vegetables. Some bogs close to cities and towns have been partly or completely filled by works of man.

The engineering problems of bogs are of a special sort. In some places where bogs have been drained and filled in, the fact that the area was originally a bog may not be realized. The construction of highways and railroads across bog areas involves severe foundation problems.

Chapter 9

SUMMARY

The following summary is based on the descriptions, analyses, maps, and history presented in this report.

1. That part of the Allegheny Plateau in northeastern Ohio was glaciated by seven or more ice sheets at various times during the Pleistocene Epoch beginning more than 1 million years ago until about 14,500 years ago. From the main lobe in the Erie basin smaller lobes extended southeast, south, and southwest. The Grand River lobe covered northwestern Pennsylvania and northeastern Ohio. The Killbuck lobe was between the higher land in Medina County and that in western Richland County. A smaller Cuyahoga lobe existed from time to time in the Cuyahoga Valley region between the Grand River and Killbuck lobes. The very extensive Scioto lobe in the Central Lowland west of the Plateau covered the area between western Richland County and the highland near Bellefontaine. The Scioto lobe extended much farther south than the lobes on the Plateau to the east; only the extreme eastern margin of the Scioto lobe extended onto the Plateau.

2. The surface of the Allegheny Plateau was more or less modified by glacial erosion. Some valleys were deepened 200 feet or more, but the uplands were much less modified. The glaciated Plateau is in contrast to the more rugged unglaciated Plateau to the south.

3. Deposits of till and outwash modified the surface and partially filled the valleys of northeastern Ohio during the Pleistocene. The deposits range in age from very early Pleistocene, possibly Nebraskan or even pre-Nebraskan, through Kansan and Illinoian to late Wisconsinan. The pre-Illinoian deposits are present in the subsurface in widely separated localities, but the correlation in age is uncertain. Illinoian deposits are more widespread, but are by no means common. Early Wisconsinan (Altonian) till and outwash deposits make up the bulk of the drift in northeastern Ohio. A narrow fringe of Altonian drift (Titusville-Mogadore-Millbrook Tills) up to 5 miles wide is at the surface in the southern margin of the lobes. Altonian deposits are almost always present below thin drift of late Wisconsinan (Woodfordian) age. The Woodfordian drift was deposited by four separate ice advances, each less extensive than the preceding one. These advances deposited the Kent-Navarre, the Lavery-Hayesville, the Hiram, and the Ashtabula Tills. Weathering profiles are preserved at some places, and buried soils overlie till or sand and gravel deposits of Nebraskan(?), Kansan, Illinoian, or Altonian age at some places.

4. As the last ice sheet disappeared, early Lake Erie was at levels more than 200 feet higher than today. As lower outlets were uncovered by the retreating ice, the lake decreased in size and elevation. The location of the shores of the progressively lower lakes are recorded by beach deposits.

5. The glacial deposits are important economically as parent materials for soil, and affect engineering conditions for highway construction, foundations, excavations, and waste disposal. Some glacial deposits are important sources of ground water. Extensive sand and gravel deposits are valuable for concrete aggregate and highway construction.

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BULLETIN 68
PLATE 1

STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Joseph J. Sommer, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

QUATERNARY

Recent and Pleistocene

al

Alluvium. Silt, sand, and gravel in floodplains and kettle holes; kettle holes may contain peat or muck; includes Wisconsinan-age alluvium in terraces of two or more levels along streams in western part of map area; streams may flow through some kettle holes. Only larger areas shown

Pleistocene (Wisconsinan)

Wl

Lacustrine plain. Silt and fine sand in Lake Plain, silty clay and clay elsewhere; at places on Lake Plain clayey till may be very close to the surface; lacustrine clay in Cuyahoga River valley in southern Cuyahoga County has thin cover of sand and gravel, which passes southward into outwash; lacustrine silty clay 1 to 5 feet thick in Rock Creek Lake south of dashed line in Trumbull County; extent of Rock Creek Lake north of dashed line not determinable, but outwash deposits indicate position of shoreline; see figure 27 in text

Wbr

Beach ridge. Sand and fine gravel; crests 5 to 20 feet above Lake Plain; may have sand dunes superimposed. Only most distinct and most continuous ridges shown

Wo

Outwash, valley trains. Sand and gravel, generally in low terraces but in some high terraces; includes deltas of Grand River Lake and some sandy silt deposits in very shallow lakes; includes pre-Wisconsinan and pre-Illinoian outwash terraces in Ohio River valley near East Liverpool; includes Recent alluvium where alluvium is too narrow to be mapped

Wk

Kames and kame terraces. Mainly sand and gravel in knolls and terraces; may be overlain by till

g

Ground moraine. Mainly till in flat to rolling topography in northern part; drift-veneered bedrock hills in southern part

e

End moraine. Mainly till in linear belts of hummocky topography; may be underlain by gravel, especially in broad end moraine belt in southern Mahoning, northern Columbiana, central Stark, central Summit, western Portage, and central Geauga Counties

h

Hummocky moraine without linear trend. Mainly till in irregular patches and along valley sides; includes some gravel in places; till-covered kames in part

Woodfordian

Ashtabula Till, ground moraine and end moraine

Hiram and Centerburg Tills, ground moraine, end moraine, and hummocky moraine without linear trend

Lavery, Hayesville, and Mt. Liberty Tills, ground moraine, end moraine, and hummocky moraine without linear trend

Kent, Navarre, and Knox Lake Tills, ground moraine, end moraine, and hummocky moraine without linear trend

Altonian

Titusville, Mogadore, Millbrook, and Jelloway Tills, ground moraine, end moraine, and hummocky moraine without linear trend.

Till identification key:

Wa, Ashtabula Till
Wc, Centerburg Till
Wh, Hiram Till
Wha, Hayesville Till
Wj, Jelloway Till
Wke, Kent Till
Wkl, Knox Lake Till
Wla, Lavery Till
Wm, Millbrook Till
Wml, Mt. Liberty Till
Wmo, Mogadore Till
Wn, Navarre Till
Wt, Titusville Till

Till distribution and composition:

ERIE LOBE

Ashtabula Till
silty till with many shale fragments

SCIOTO LOBE	KILLBUCK LOBE	CUYAHOGA LOBE	GRAND RIVER LOBE
Centerburg Till clayey till	Hiram Till clayey till	Hiram Till clayey till	Hiram Till clayey till
Mt. Liberty Till silty till	Hayesville Till silty till	Lavery Till silty till	Lavery Till silty till
Knox Lake Till sandy till	Navarre Till sandy till	Kent Till (subsurface only) sandy till	Kent Till sandy till
Jelloway Till sandy coarse till	Millbrook Till sandy coarse till	Mogadore Till sandy coarse till	Titusville Till sandy coarse till

Pleistocene (Illinoian)

Ib

Ground moraine. Sandy Butler Till, very thin, discontinuous, deeply weathered; at surface in southern Richland and southwestern Ashland Counties; in subsurface in places below Altonian tills in all lobes

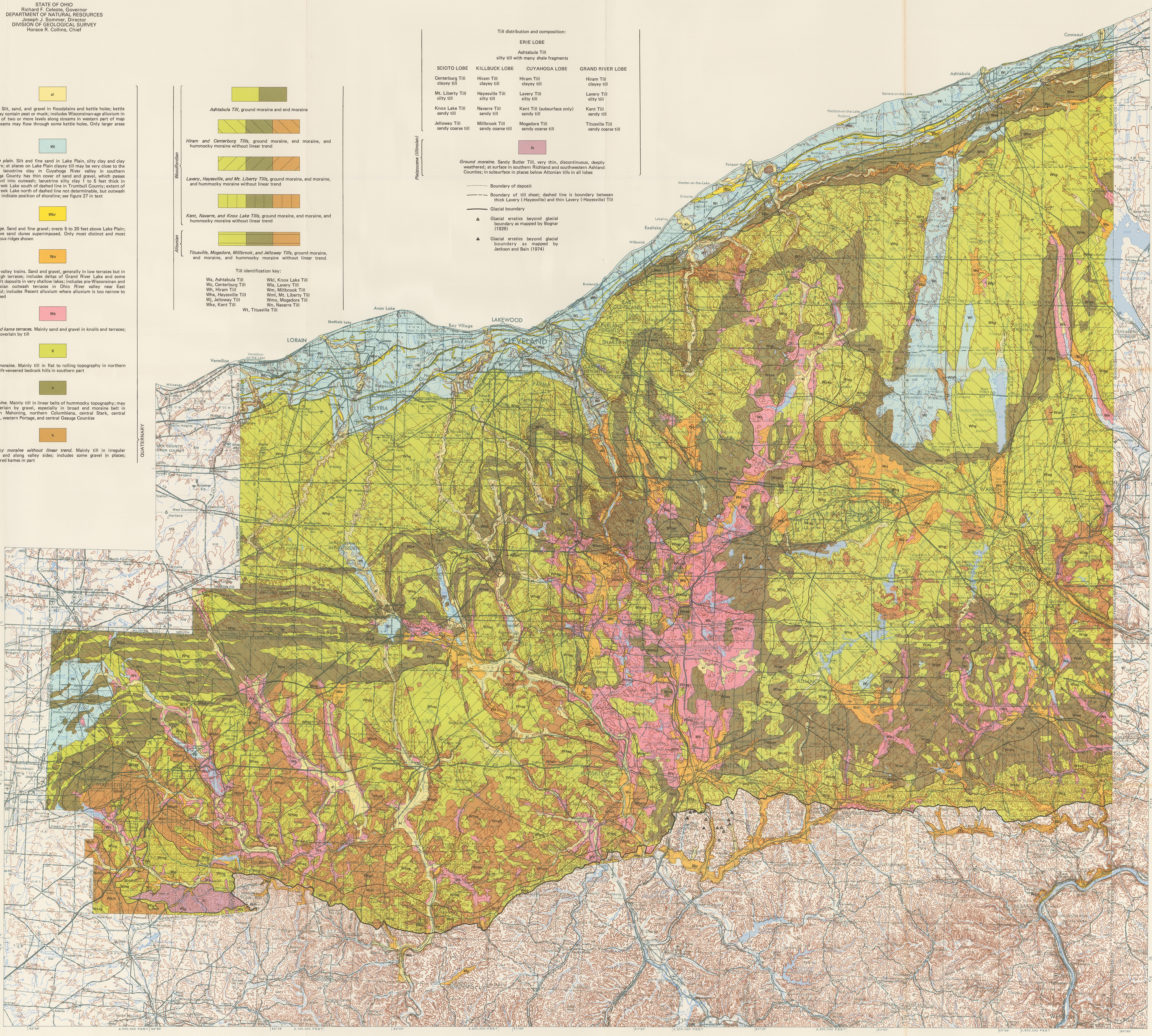
Boundary of deposit

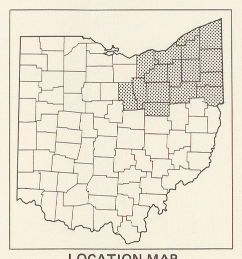
Boundary of till sheet; dashed line is boundary between thick Lavery (-Hayesville) and thin Lavery (-Hayesville) Till

Glacial boundary

△ Glacial erratics beyond glacial boundary as mapped by Bognar (1926)

▲ Glacial erratics beyond glacial boundary as mapped by Jackson and Bain (1974)




LOCATION MAP

100,000-foot grid based on Ohio coordinate system, north zone
Areas outlined by light-blue dashes are subject to controlled inundation

BASE COMPILED FROM THE FOLLOWING 1:250,000 U.S. GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLE MAPS

Canton　Marion
Cleveland　Toledo

GLACIAL GEOLOGY OF NORTHEASTERN OHIO

by George W. White

1982

Reprinted 1987

Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

CONTOUR INTERVAL 50 AND 100 FEET

TRANSVERSE MERCATOR PROJECTION

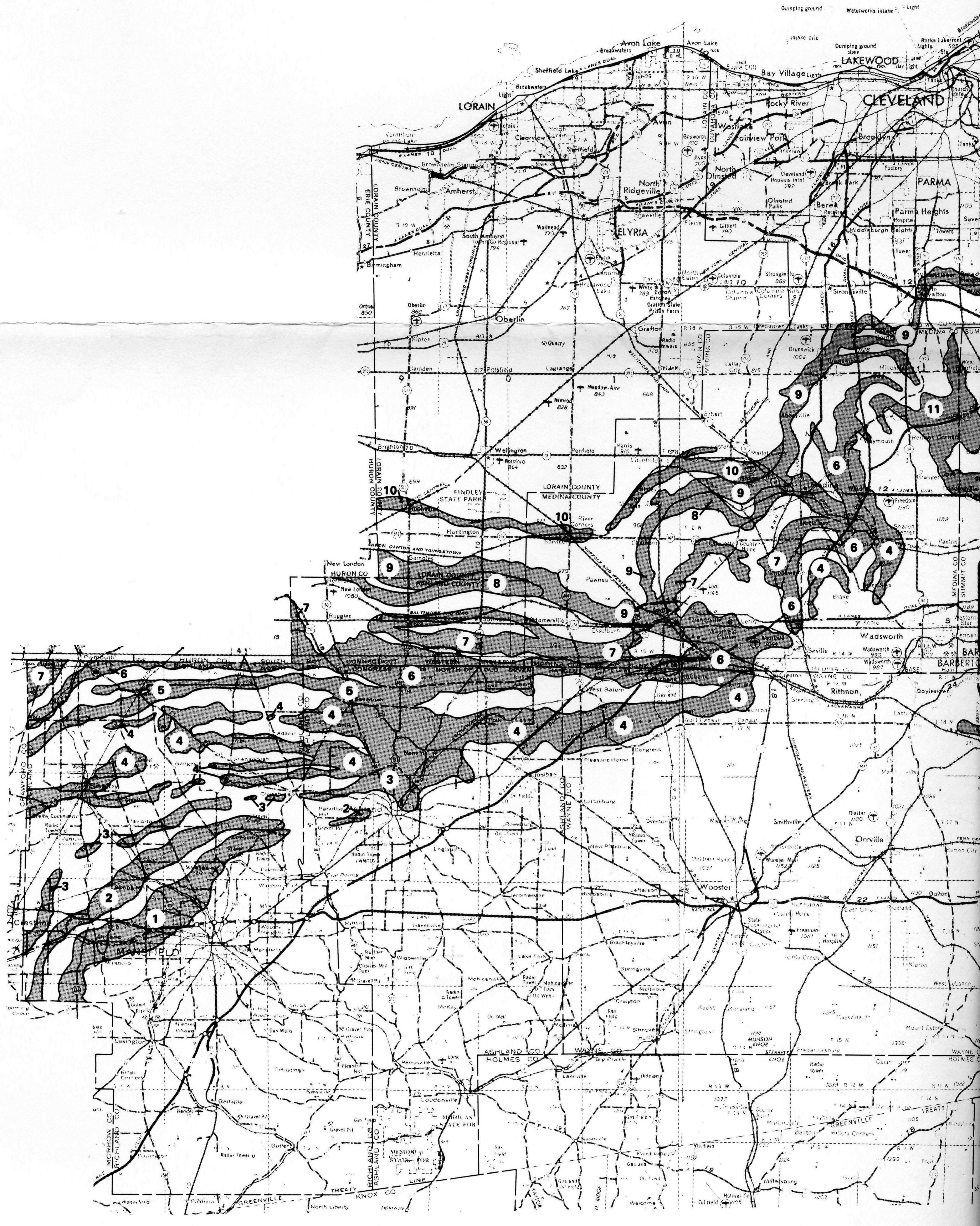
APPROXIMATE 1967 MAGNETIC DECLINATION FROM TRUE NORTH IS 4° (71 MILS) AT CENTER OF MAP

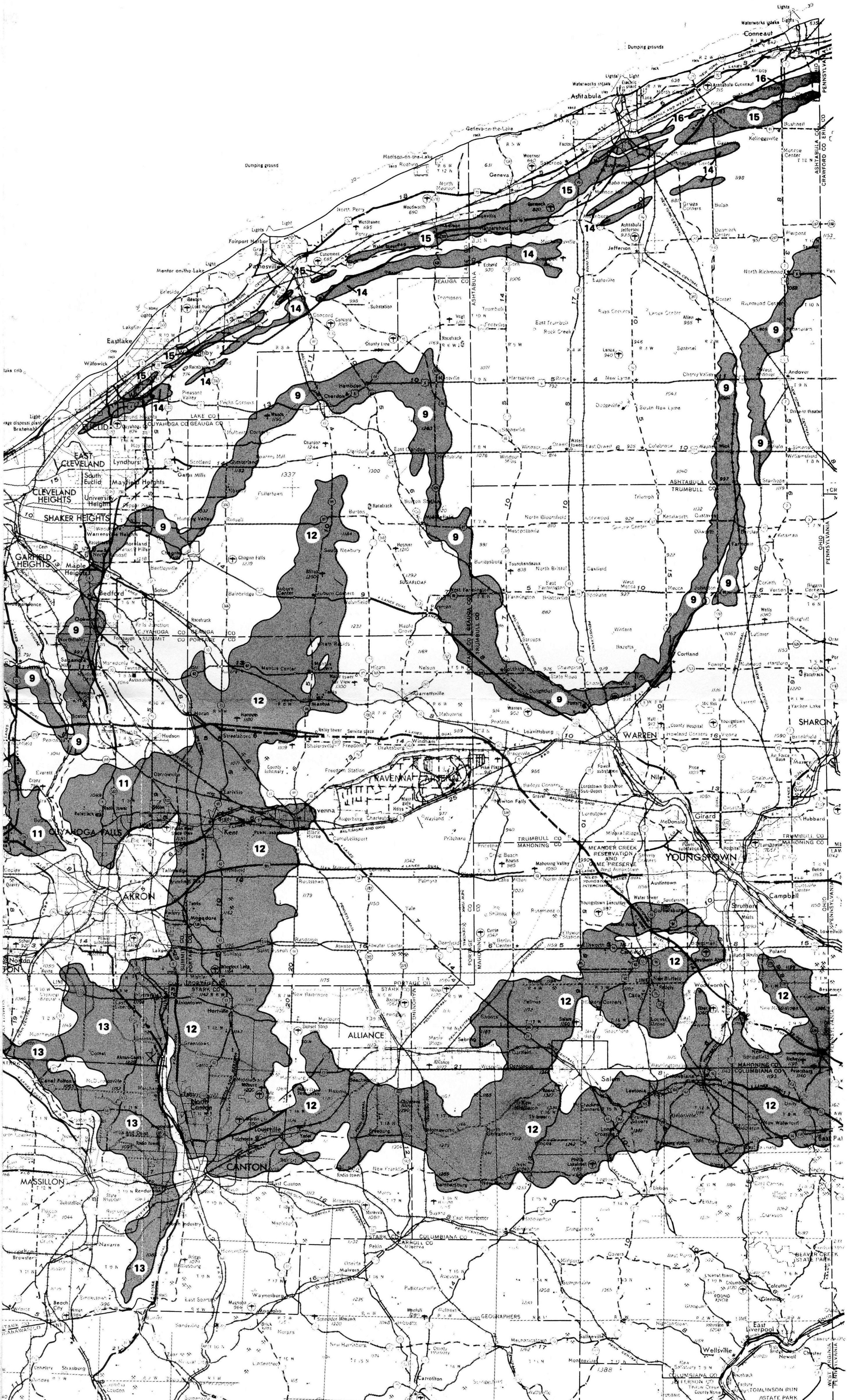
Cartographic drafting by James A. Brown

eres
008

FIGURE 6.–End moraines in northeastern Ohio.

1 Johnstown Moraine
2 Powell Moraine
3 Broadway Moraine
4 Mississinewa Moraine
5 St. Johns Moraine
6 Wabash Moraine
7 Fort Wayne Moraine
8 New Washington Moraine
9 Defiance Moraine
10 Spencer Moraine
11 Summit County morainic complex
12 Kent Moraine
13 Buck Hill Moraine
14 Euclid Moraine
15 Painesville Moraine
16 Ashtabula Moraine





Conneaut
Ashtabula
Geneva-on-the-Lake
Madison-on-the-Lake
Geneva
Fairport Harbor
Painesville
Mentor-on-the-Lake
Eastlake
Willowick
Willoughby
Kirtland
Euclid
East Cleveland
Lyndhurst
South Euclid
Mayfield Heights
Cleveland Heights
University Heights
Shaker Heights
Garfield Heights
Maple Heights
Bedford
Solon
Chagrin Falls
Chardon
Hambden
Montville
Jefferson
Andover
Cherry Valley
Orwell
Middlefield
Burton
Auburn Corners
Mantua
Garrettsville
Hiram
Warren
Cortland
Niles
Girard
Youngstown
Struthers
Campbell
Sharon
Hubbard
Hudson
Kent
Ravenna
Ravenna Arsenal
Cuyahoga Falls
Akron
Tallmadge
Mogadore
Hartville
Uniontown
Alliance
Sebring
Salem
Columbiana
Leetonia
Lisbon
Canton
North Canton
Louisville
Massillon
Canal Fulton
Navarre
Minerva
Malvern
Waynesburg
Carrollton
Wellsville
East Liverpool
Meander Creek Reservation and Game Preserve
Beaver Creek State Park
Tomlinson Run State Park
Ashtabula Co
Trumbull Co
Lake Co
Geauga Co
Cuyahoga Co
Summit Co
Portage Co
Stark Co
Mahoning Co
Columbiana Co
Carroll Co
Jefferson Co
Pennsylvania
Ohio
West Virginia
9
11
12
13
14
15
16